MCST Walkthrough on MODIS Development

I recommend that everyone print a copy of charts from this initial file *(MCST/MODIS to IPO-Briefing.ppt)* to follow the flow of the briefing. Other files are supplemental and can be read from a computer screen as these are discussed.

The organization of this briefing goes:

Beta Science Images --**SEE FILE NAME: *MODIS Beta Science Images***

BACKGROUND -- **SEE FILE NAME: BACKGROUND**

MCST/MODIS to IPO-Briefing.ppt -- **THIS FILE**

Spatial -- **SEE FILE NAME: *SPATIAL***

Spectral --**SEE FILE NAME: *SPECTRAL***

Radiometric --**SEE FILE NAME: *RADIOMETRIC***

If you don’t like some of the characterizations, or think it is too hysterical, Guenther gladly accepts that “credit.”

MCST, B. Guenther, Head
301-943-0350
Guenther@mcst.gsfc.nasa.gov

SPATIAL

- Principle Test Equipment
  - Integration and Alignment Collimator system (IAC)
- Test Issues & Concerns
  - Positioning of bands along focal plane based on optimization of science for co-registration
  - Potential thermal and temporal variability of co-registration (in FM1 T/V)
  - Spectral leaks, cross-talks, etc, have spectral/temporal/ spatial weighting functions that need to be applied
  - Bands 1-7 are super-sampled; super-frame 1 in Bands 5/7 sampled same time as super-frame 2 in Band 6
  - Minor IFOV non-compliance
  - Boresight alignment accuracy & knowledge waved from 108 & 90 arcsec to 300 arcsec 3-axes, 3-σ

SPECTRAL - I

- Principle Test Equipment
  - Spectral Measurement Assembly (SpMA)
    - 0.25 m double monochromator (w/ dual grating drives)
      - Saved ~$10K -20K over 0.5 m w/single grating drive
      - SBRS and MCST each spent several times more in analysis costs due to complexity of dual drives than was saved
      - Intrinsic reduction in spectral characterization accuracy and precision
  - Hallow cathode spectral line sources
  - Neutral Density filters
    - Filters and data set filtering used to cover Relative Spectral Response over 4-6 orders

SPECTRAL - II

- Test Issues & Concerns
  - Optics not specified for scattering characteristics (Harvey-Shack parameters)
  - Uniformity of Spectral Measurement Assembly (SpMA) across MODIS aperture (smile)
  - PFM used CaF_2 window on SpMA chamber aperture
  - FM1 used ZnSe window on SpMA chamber aperture
  - Ghosting
    - Better A-R coatings, intermediate filtering and tilted RC window
  - Clipping of peak RSR in SWIR
  - Numerous inconsequential spectral specification violations
  - PFM PV LWIR long wavelength OOB measurement not useful
    - PFM uses FM1band-average measurements

SPECTRAL - III

- Test Issues & Concerns (continued)
  - RSR sensitive to atmospheric transmission effects
  - Spectral leaks
    - SWIR 5 μm thermal leak
    - PC LWIR Band 31 leaks into Bands 32 - 36
  - TEB RSR (in principle) FPA temperature dependent
  - Reflected Solar Bands (RSB) filters ion-assist deposition "hardened" but dichroics were not (effect known in Landsat as air-vacuum shift)
    - **LESSON - NO OBSERVED WAVELENGTH SHIFT THESE BANDS**
  - Long λ Band 27 cut-off on Intermediate Stage cooler window
    - Cooler loss of margin continuously across mission
    - Outgas recovery in August; slower rate to loss of margin
  - SpMA output is polarized

Radiometric - I

- Principle Test Equipment
  - Spherical Integrator Source (SIS)
  - Solar Diffuser
  - Polarization Source Assembly (PSA)
  - Blackbody Calibration Source (BCS)
  - On-board Calibrator - Blackbody (OBC-BB)
- Test issues & concerns
  - **Detector division *MUST* revise channel ordering convention for VIIRS**
  - Cross-talk
    - Electronic
    - Optical: thermal 5 μm and Band 31 optical
  - Large dynamic range/large quantization
  - Response versus scan angle not measured on PFM
    - Witness samples measured at Lincoln Labs and National Physical Laboratory
  - Channel-to-channel and mirror side - to -mirror side differences
    - Image banding and striping: serious implications for validation
    - Ocean products required precision _ to full order magnitude more demanding than can be obtained with OBC systems

Radiometric - II

- Test issues & concerns
  - ADC not properly tested at component level
    - 16-bit DAC for 12-bit system
    - Raw data not saved
    - Probably missing codes present at sub-system level
    - Specification identified as Differential Non-Linearity
    - Seen on orbit as fuzzy histograms (of frequency of occurrence of DN values)
  - Inadequate GSE data system
    - Never acquire full “video” or multiple OBCs data sets simultaneously
    - Analysis mainly of 1 channel per band, single mirror side
  - Engineering Model not fully built; poorly tested; data not analyzed carefully
    - SW/MWIR detectors “hotter” for flight deliveries
  - “Better” FPA-bias selected after EM but not verified
  - Radiometric Math Model not effective/useful
  - Long-term radiometric stability not demonstrated

Radiometric - III

- Test issues & concerns
  - Several channel-to-channel uniformity specifications missed (out of family gains)
    - FPA bias tests (Electronic X-talk) induced OOF gains and non-functional detectors
  - Science wanted radiometric accuracy from 0.3 L_{typ} to 0.9 L_{max}, not L_{typ} to unspecified peak
  - Data packets formatted so bands earth-registered in packets
  - Round-robin comparisons for SIS, SD/BRF but not BB
    - Did not verify relationship between NIST temp and radiance scale
  - Several SNR & NEdL out of specification instances
  - Full testing at 3 temperature plateaus, 3 detector set points in primary and redundant electronics expensive, without any cross-strapping
  - Absolute radiometric accuracy measured at one angle (AOI)
    - Never verified against a dynamic background

Radiometric - IV

- Test issues & concerns
  - Screen transmission highly structured (SD & SDSM)
  - Near and far-field optical scattering
  - No validation of scatter characteristics, any aperture (PFM)
  - No verification of accuracy of reflectance-factor product for RSB
    - Calibration for reflectance-factor in water vapor bands far exceeds capability for radiance calibration in those bands, if SD is “featureless” in those bands too
  - PSA anomalous behavior
    - alignment difficult to achieve
    - 4 Θ response
    - Drift (0° and 360° responses did not match)
  - Missed polarization sensitivity many bands, some AOIs
  - SIS 100 calibration time consuming and expensive
  - SIS uncertainties did not allow determination of RSB non-linearity

Radiometric - V

- Test issues & concerns
  - SD BRF near 2.1 μm (radiance measurements near any water vapor features)
  - FM1 detector de-lamination
  - SWIR bands generally not functional in ambient with BTC
    - RC rework and improved rejection coatings not a fundamental help
  - SDSM never tested for performance on ground

Radiometric - VI

- Test issues & concerns
  - Missed L_{max}/T_{max} for some bands; T_{sat} ~ 300 K on FM1 numerous bands
  - Band 21 fire band tested only to ~ 3.5% full scale
  - Passive cooler contamination
  - Band 27 linear gain is RSR dependent
  - BCS BB steps equal temperature range not equal radiance steps for PFM
  - Primary radiometric T/V calibration objective in TEB was OBC-BB emissivity determination wrt ε BCS
  - BCS Temperature in-range "green Light" strategy for PFM T/V
  - Algorithm in TEB uses linear gain determination each scan line (or 41 line average)
    - a_0, a_2 from pre-launch and updated on orbit with OBC-BB temperature cycle
  - PC LWIR detector drift with OBC-BB heater cycling

Items not yet addressed in L1B Production algorithm

- Polarization effects, Bands 8 - 10
- Striping and banding improvements
- SDSM screen transmission models
- Changes with time of radiance (or reflectance factor for that matter too) calibration
- Corrections due to voltage drift when sun comes off/on solar array
- Improvements to provisional optical cross-talk corrections
- Thermal bands linear gain appears weak function source temperature
- Band 27 RSR/gain dependence on radiative cooler intermediate window temperature
- Implementation of Uncertainty Index
- Quality Assessment and Validation testing

Flight Operations and L1B Product Lessons-Learned

- MCST is responsible for Flight Operations and development of the Calibration (L1B) code
  - Today’s briefing touched on almost none of these experiences and provides almost no lessons-learned in these areas

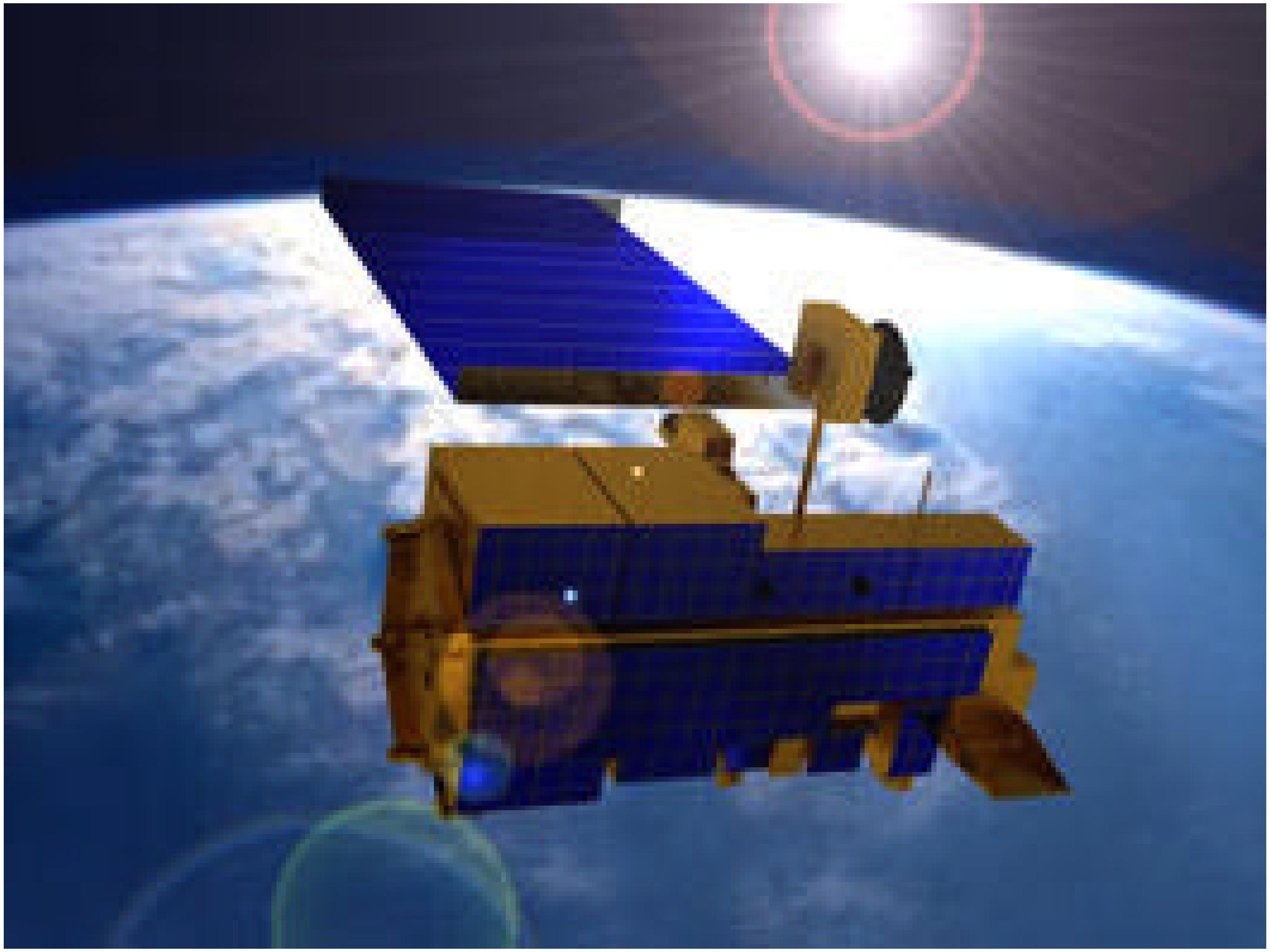
Credits

- Contributions come from the entire MCST workforce. Particular extra credit (as I can remember it) goes to Harry Montgomery, Gerry Godden (deceased), Dr.Ed Knight, Jack Xiong, Ken Anderson, Mike Roberto, Mitch Davis, Bob Martineau, Kirsten Parker and George Daelemons.
- Science Team Members & reps who also have been ready to help understand sensor/science issues are Bill Barnes, Wayne Esaias, Bob Murphy, Peter Minnett, Chris Moeller and Eric Vermote.
- Jim Young, most of MODIS Project Managers, all of the MODIS Systems Engineering staff and **many others** at SBRC/SBRS have had positive influence on these struggles, and we are getting better science products as a result of these contributions.

MODIS Beta Science Images Introduction

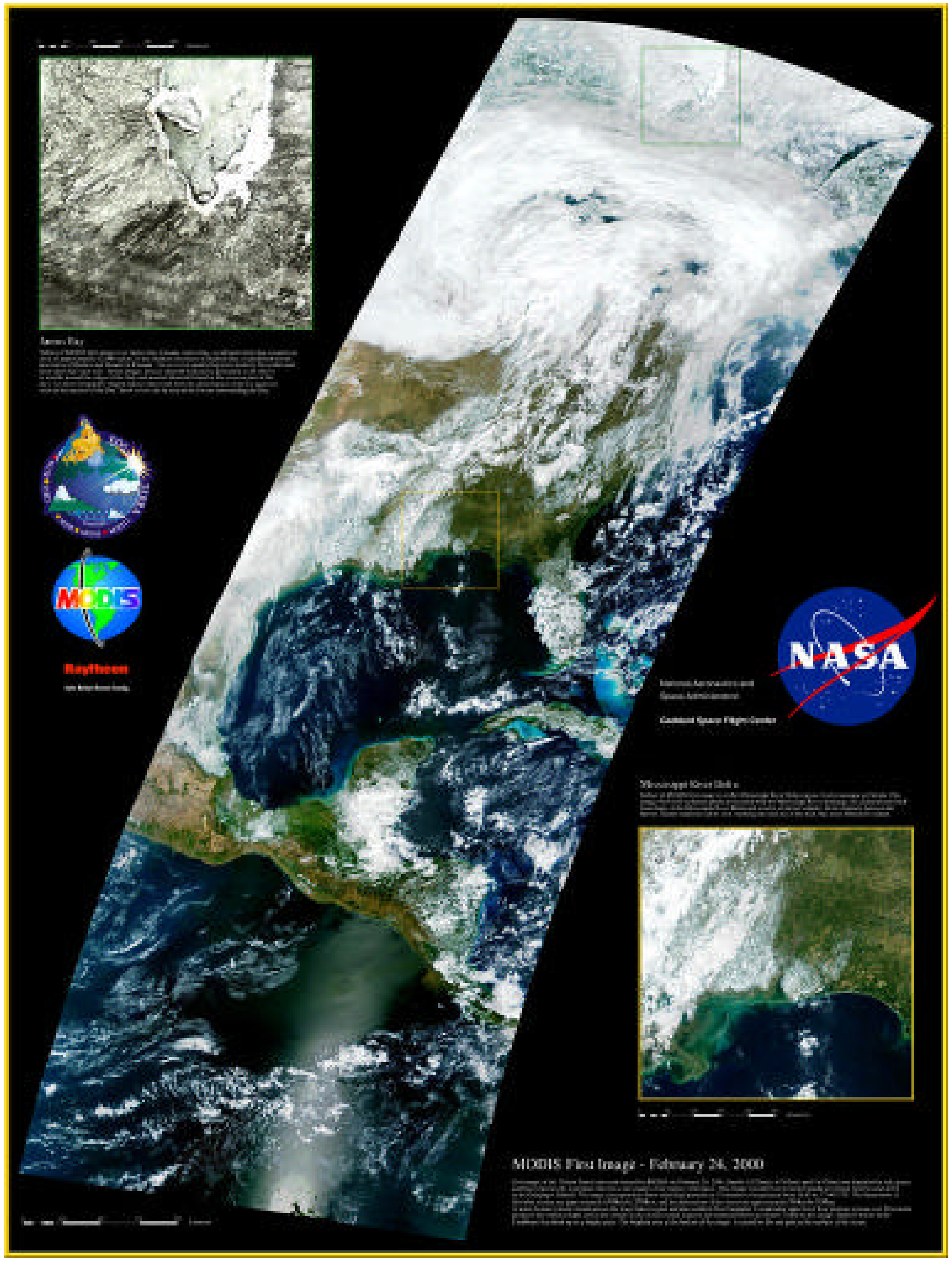
Terra Launch on December 18,1999

Terra



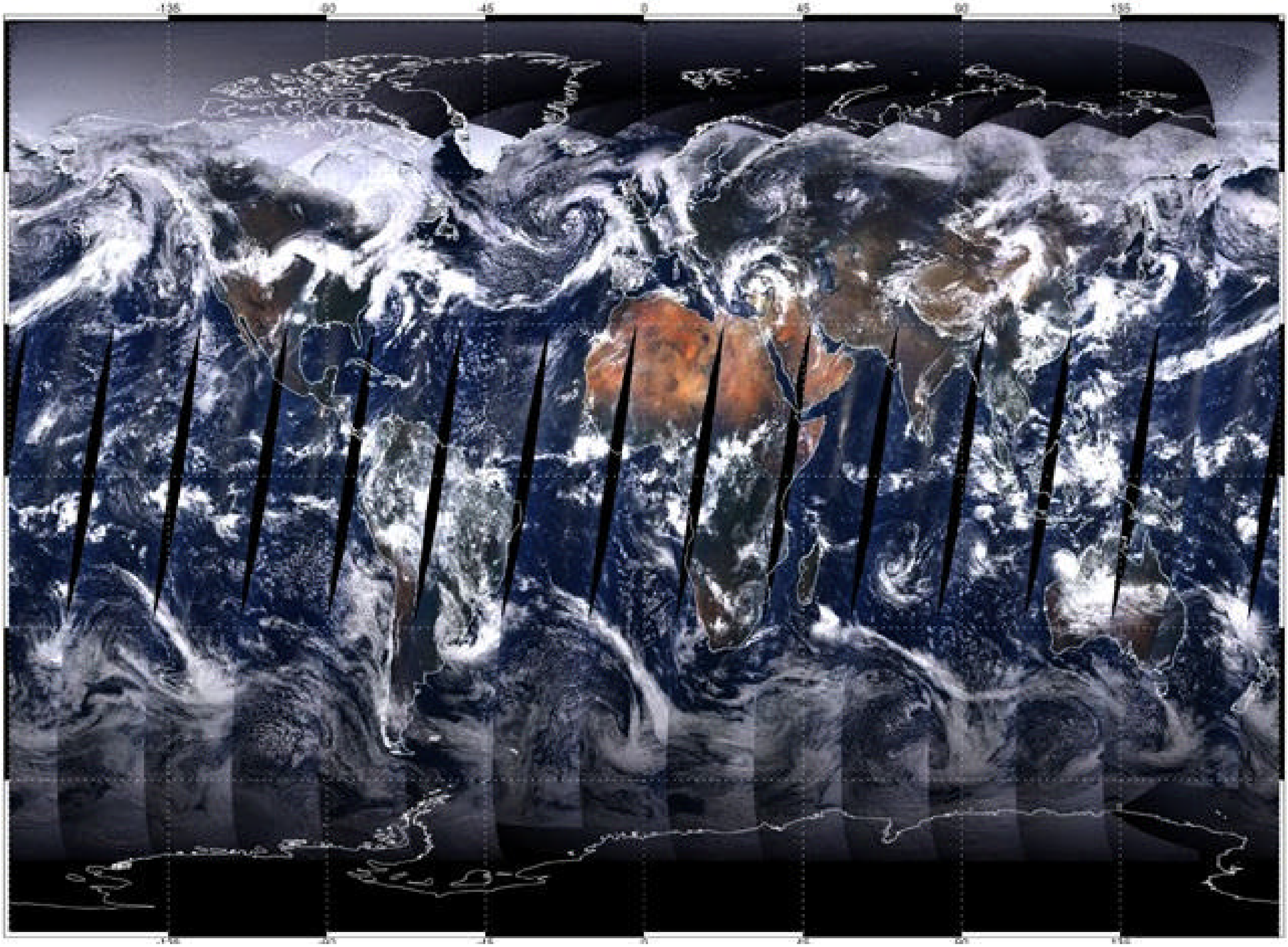
MODIS FIRST IMAGE (2/24/00)

Land sfc reflectance RGB 2,1,3



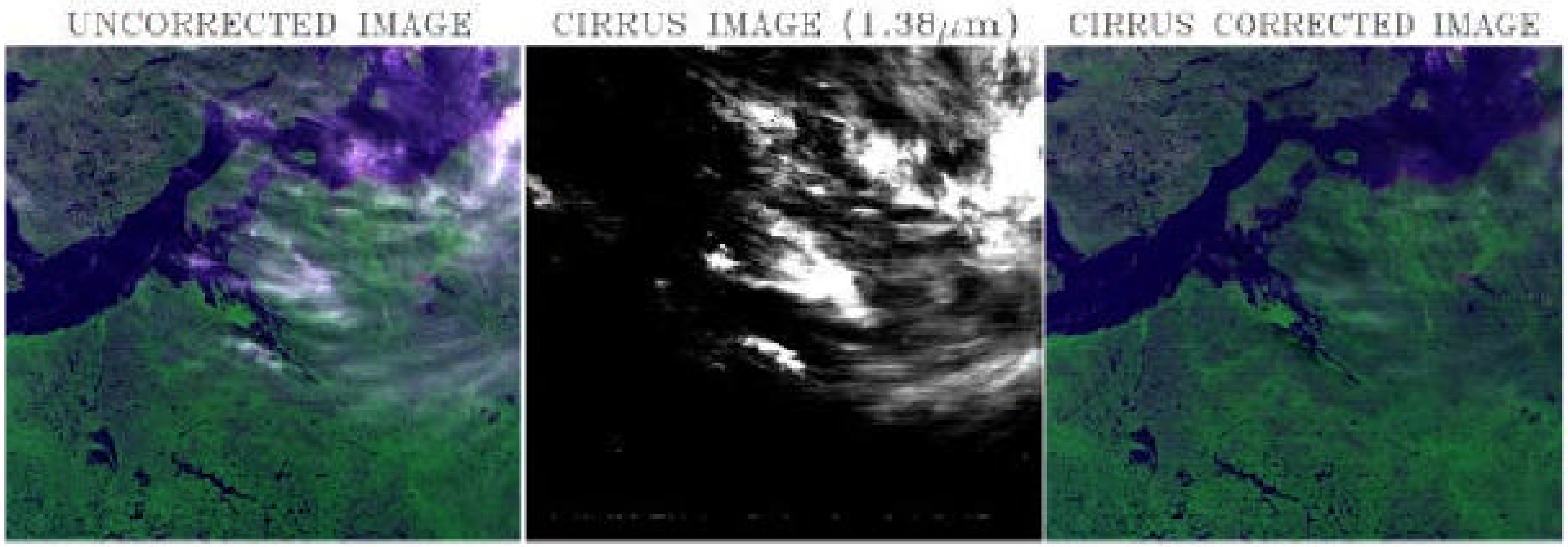
Note: As crossing times drifts to 10:15 over the next two years, glint region will move to the east

MODIS Composite April 19, 2000



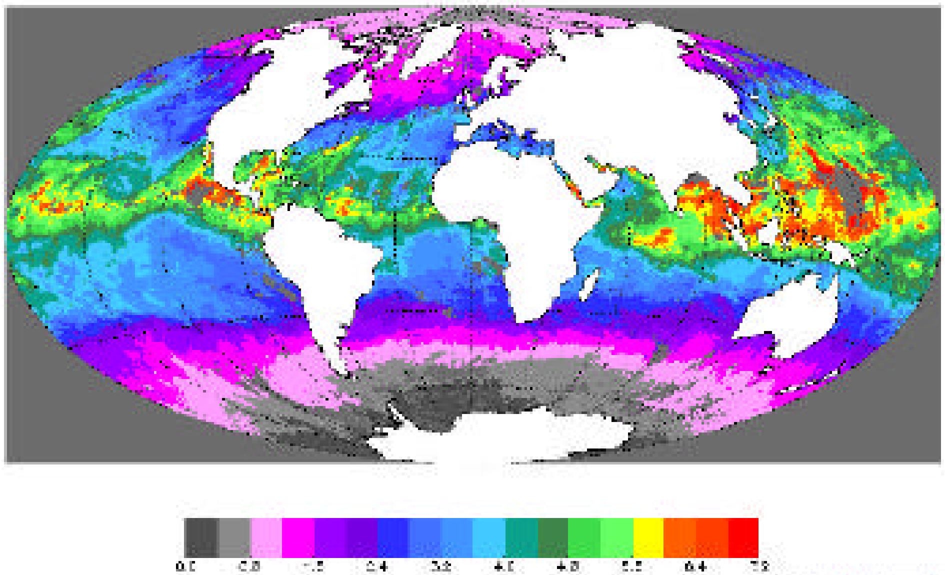
Thin Cirrus Correction Example
(Gao et al.)

MODIS DATA, CANADA, 9/2/2000 at UTC 19:15 (246.1915)



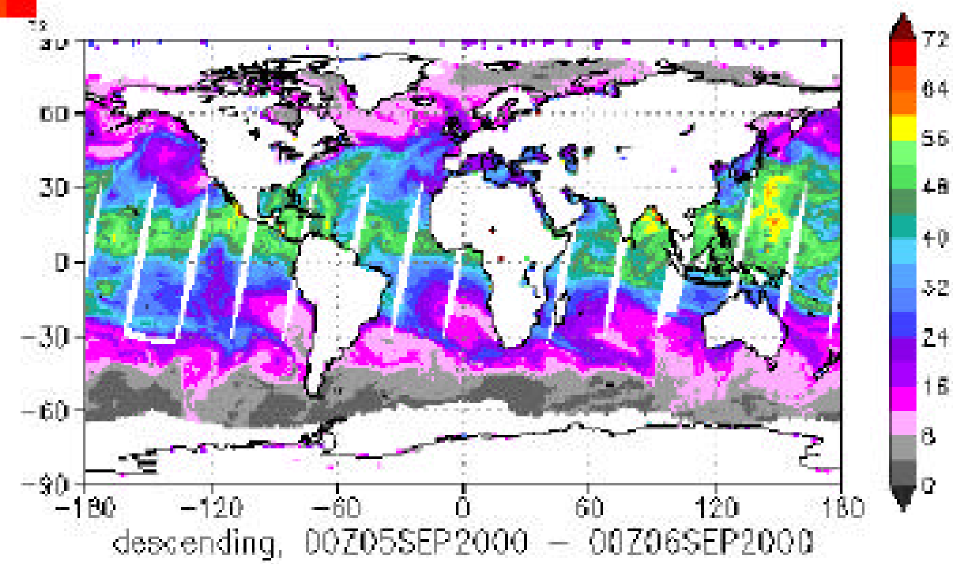
Gao, et al.

MODIS and AMSU Comparisons
(Menzel/U. of Wisc.)



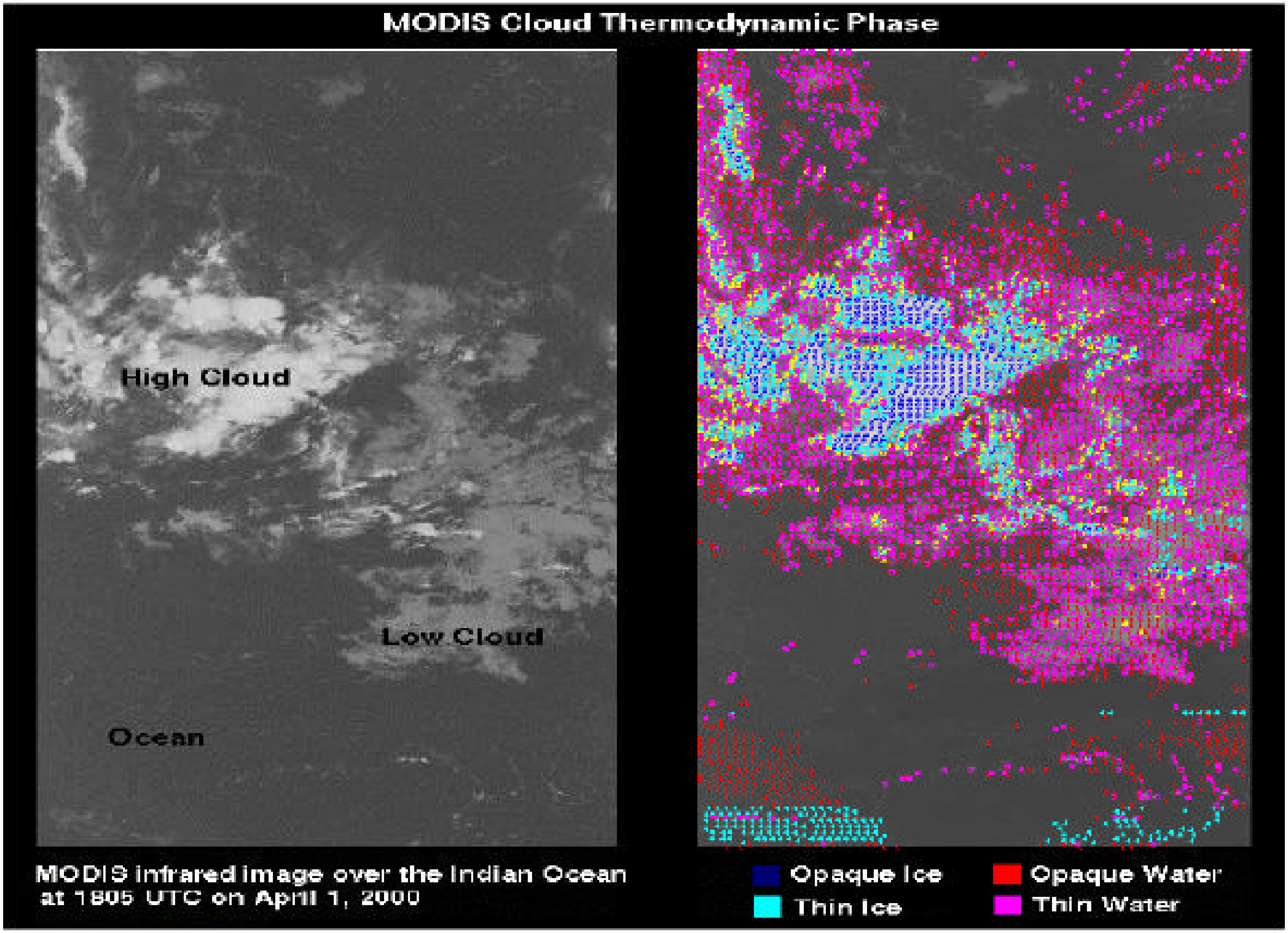
MODIS 2000/09/05-08
Daytime Total Precipitable Water (cm)
values over land not shown to facilitate comparison with AMSU

NOAA-15 AMSU-A 2000/09/05
Daytime Total Precipitable Water (mm)



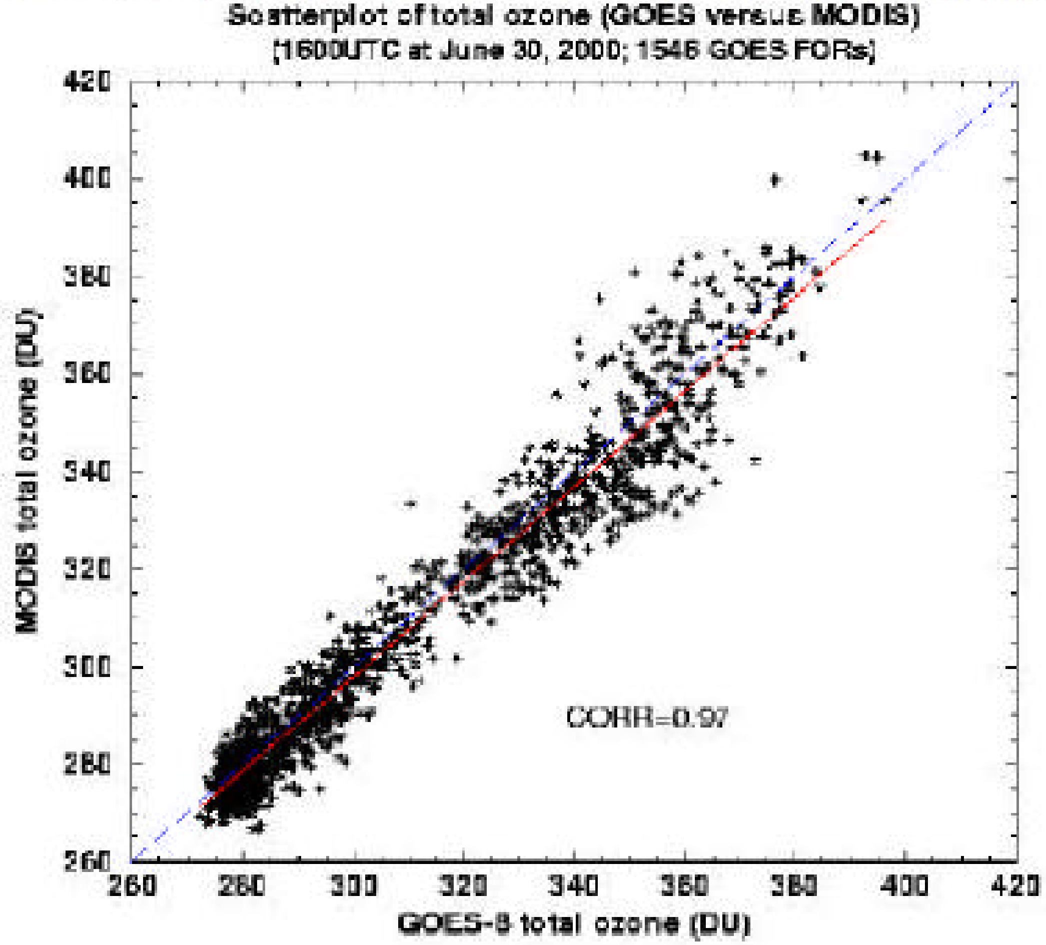
Menzel, et al.

CLOUD THERMODYNAMIC PHASE
(Univ. of Wisc.)



MODIS and GOES Ozone Plot
(Menzel, et al./U. of Wisc.)

MODIS ozone is very close to the GOES ozone; *rms* of about 10 Dobsons; polar extreme ozone values will be improved

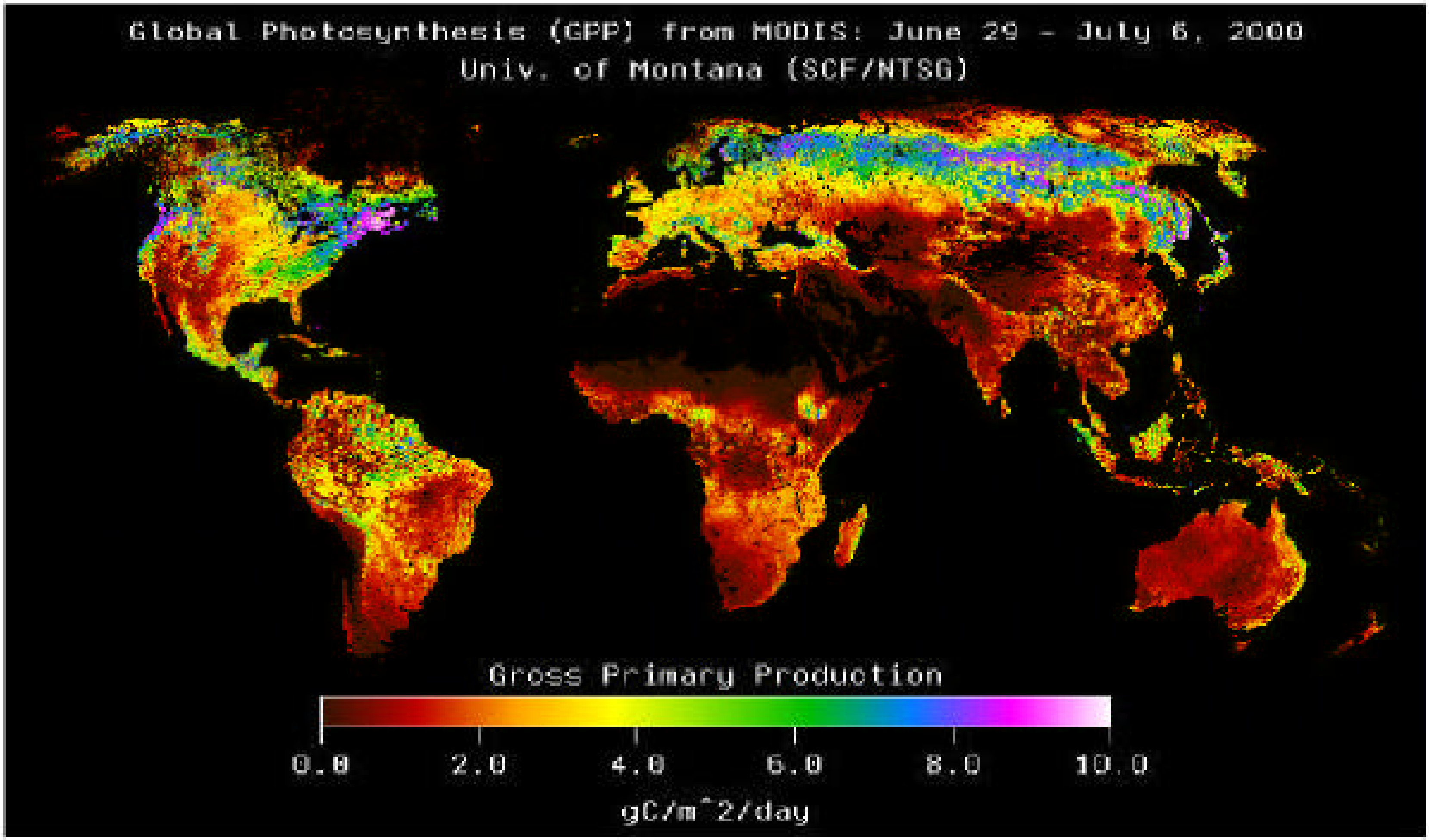


Menzel, et al.

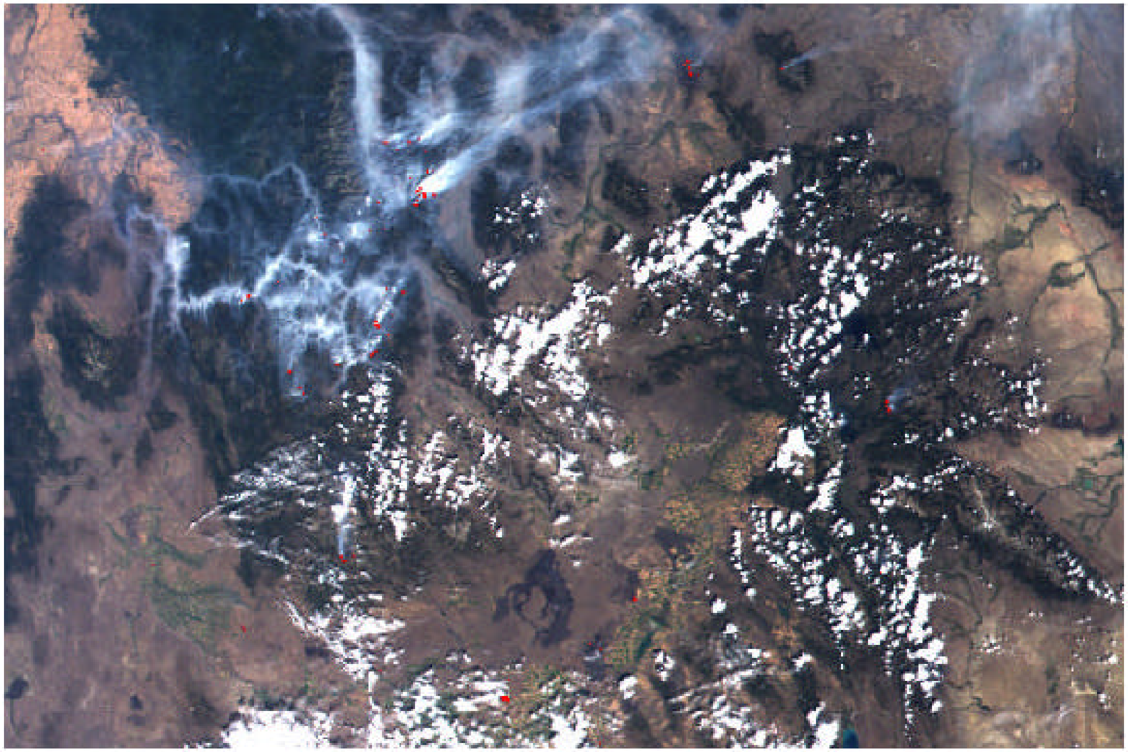
MODIS images over China with and without aerosol correction (Vermote/U. of MD)

Comparison of RGB composite over China corrected for aerosol (left) versus uncorrected (right)

Global Photosynthesis (Level 4 Product)
June 29-July 6, 2000 (Running, et al./U. of Mont.)



MODIS detects Fires!



Day 236

Acquired Aug. 23

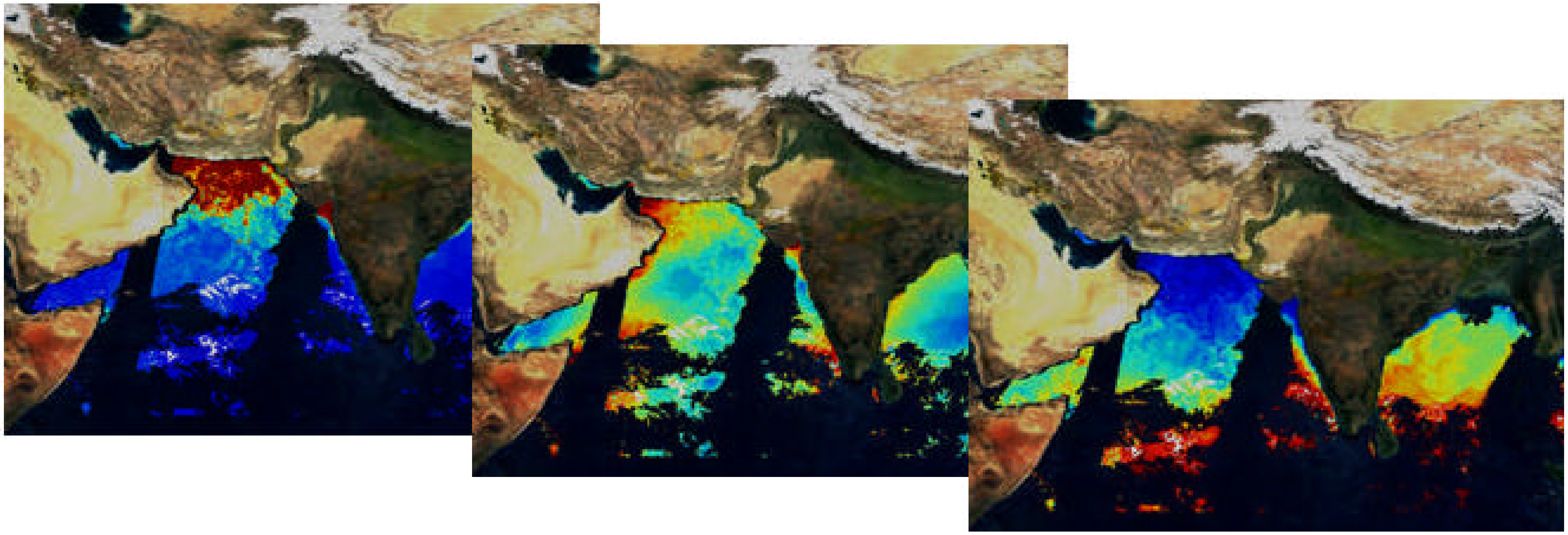
Produced Aug. 30

True-color image of smoke & burn scars over Montana

fire pixels added using 3.75 µm channel

By Rong Rong Li

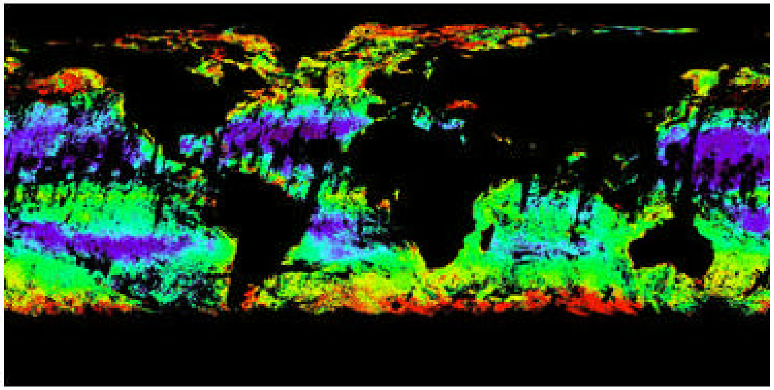
Fluorescence - MODIS' New Insight into the Marine Biosphere



MODIS provides the first routine views of sun-stimulated fluorescence from space, thereby allowing us to study the health of the phytoplankton.

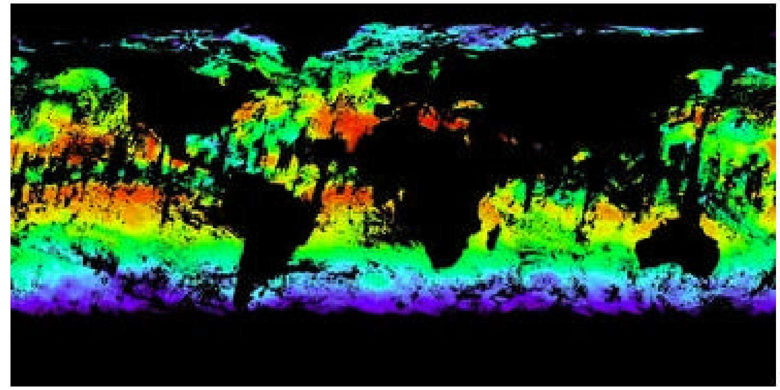
- When under stress, phytoplankton no longer photosynthesize well, and emit stored sunlight as fluorescent light
  - In the top left image, reds shows high concentrations of marine plants
  - In the center image, reds shows high levels of fluorescence
  - In the right image, the blues indicate high photosynthesis by the phytoplankton, red is lower photosynthesis per cell. **M. Abbott/J. Barlett/R. Letelier**

Ocean Weekly Productivity Index Inputs Week 233

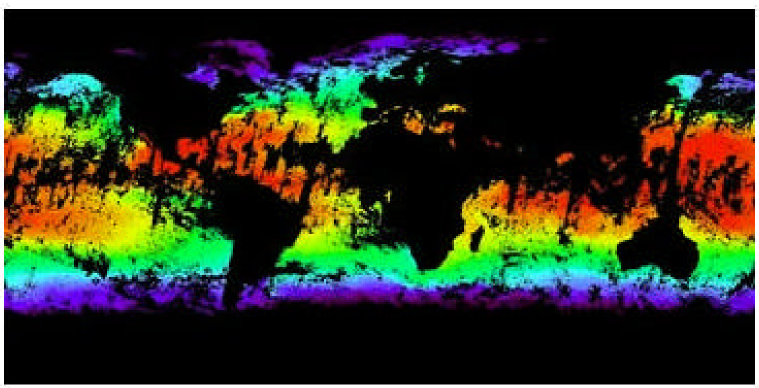


MODIS Chlorophyll

0 50 100 W/ m2

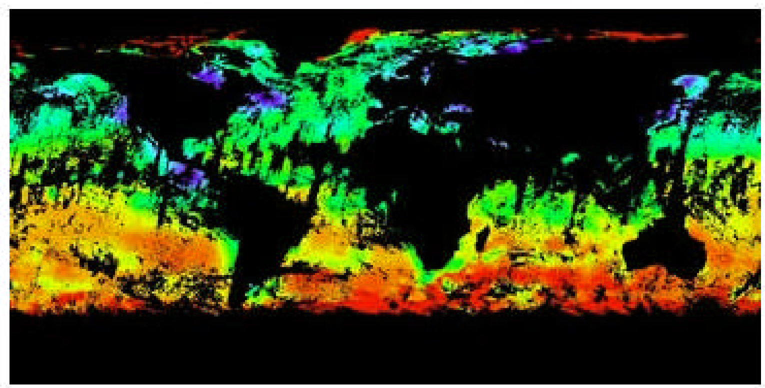


DAO PAR radswg



MODIS SST 11-12 µm Day

0 16 32 C

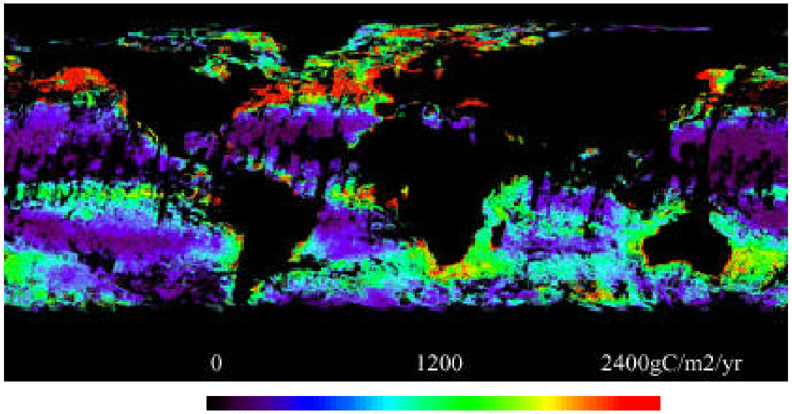


FNMOC Mixed Layer Depth

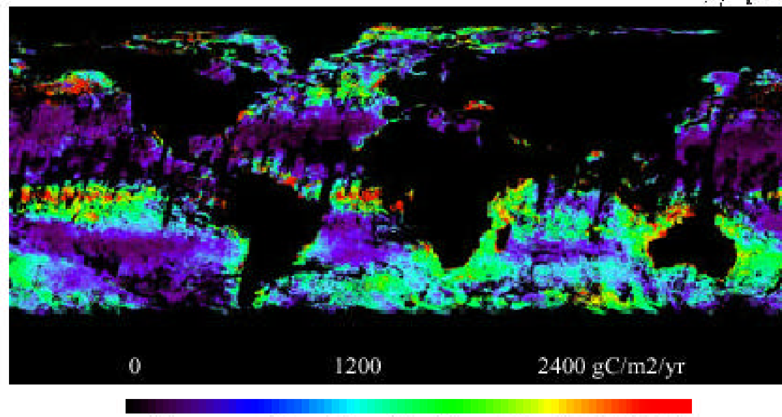
0 200 400 m

Esaias, Iverson, Turpie

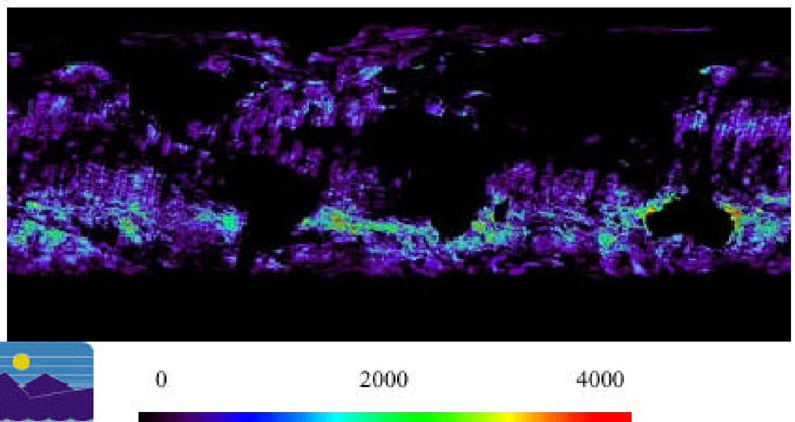
L-4 Weekly Ocean Productivity Indexes



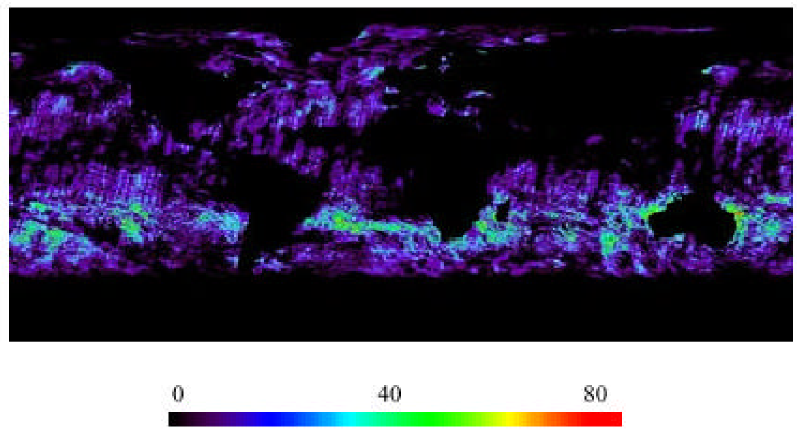
Ocean Productivity P1



Ocean Productivity P2 (H/Y/R)



Number of pixels

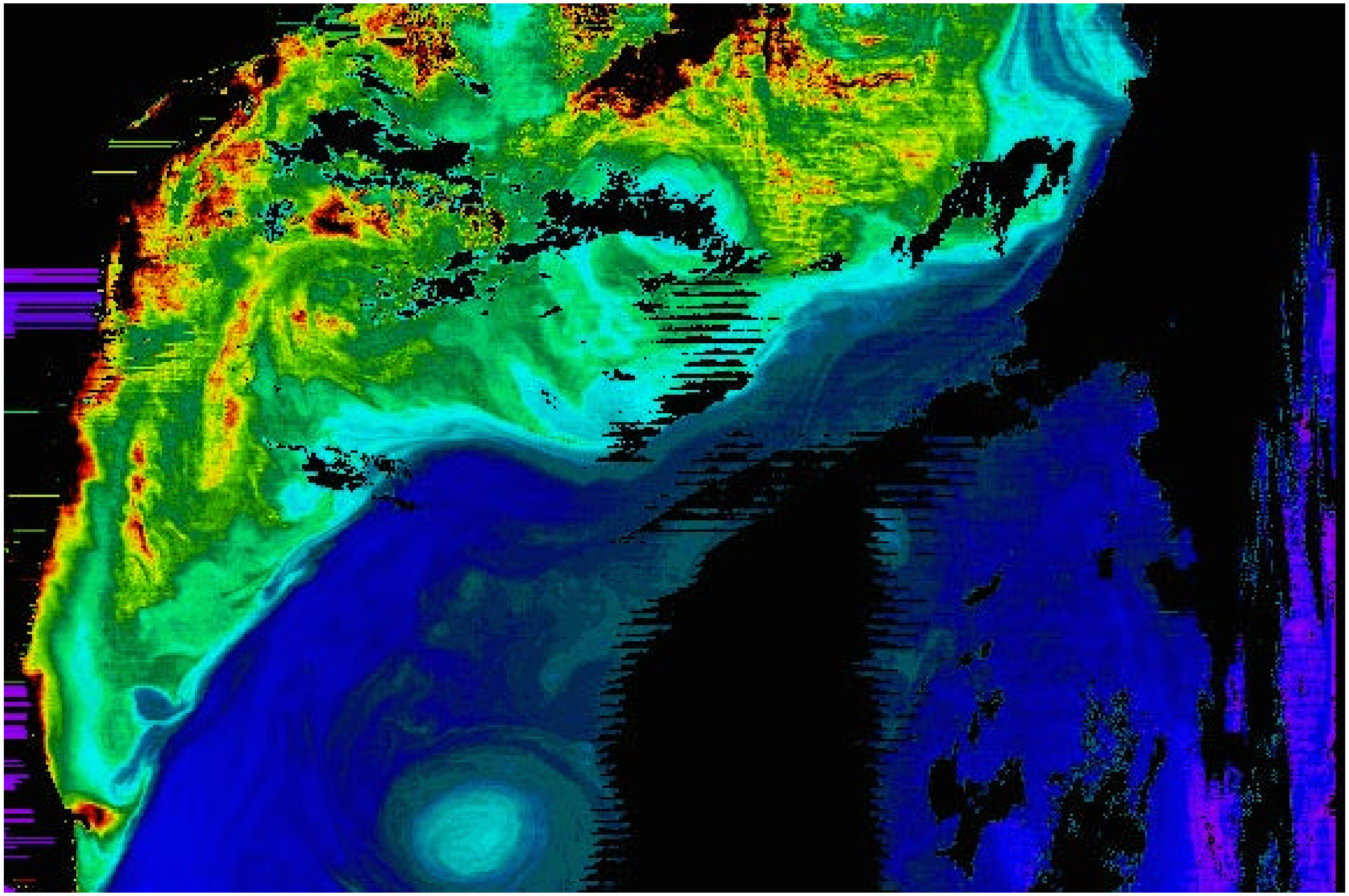


Number of granules

Test - Unvalidated, for Week 233, 2000, 36 km

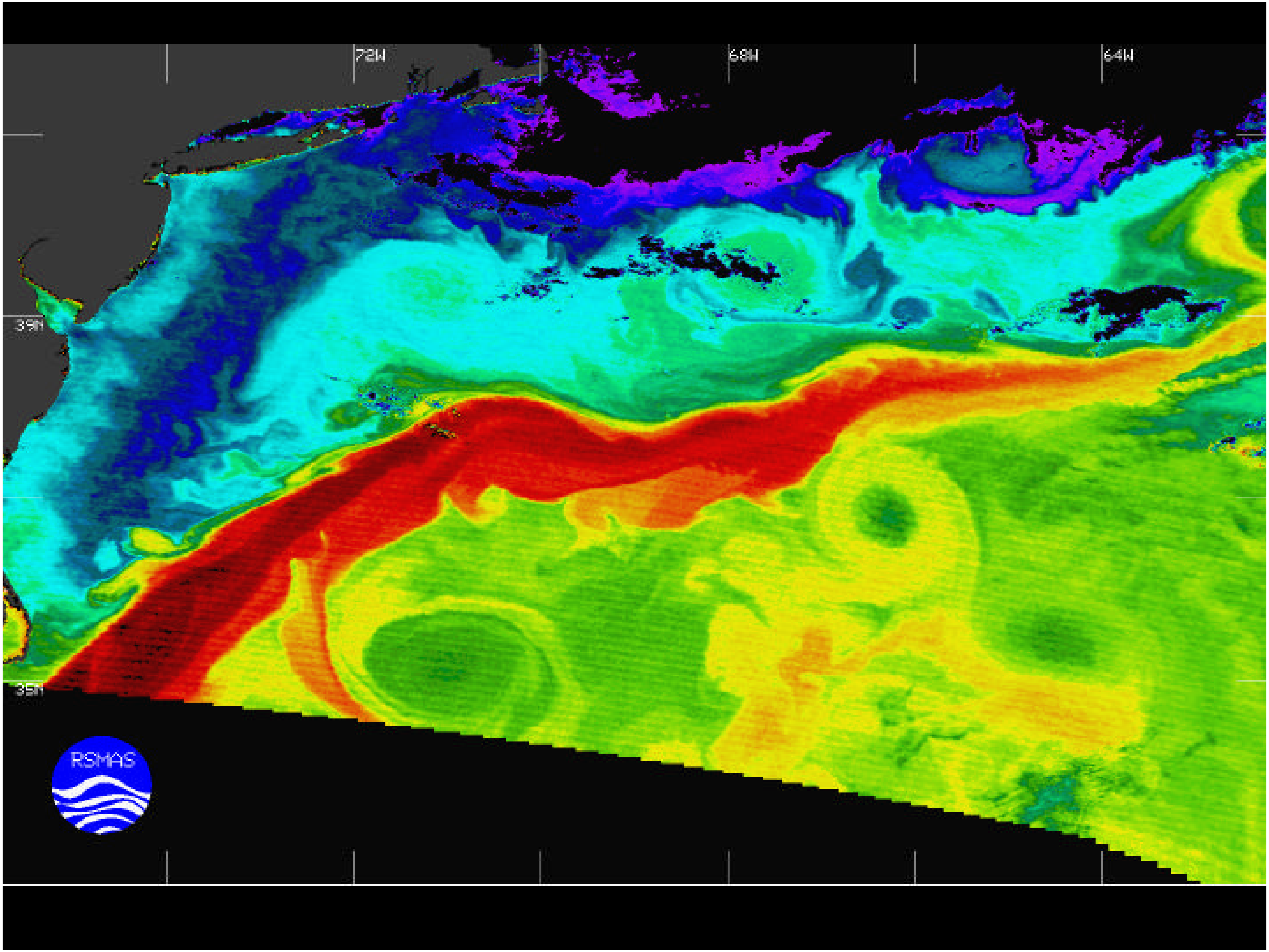
Esaias, Iverson, Turpie

W. N. Atlantic Chlorophyll - May 8



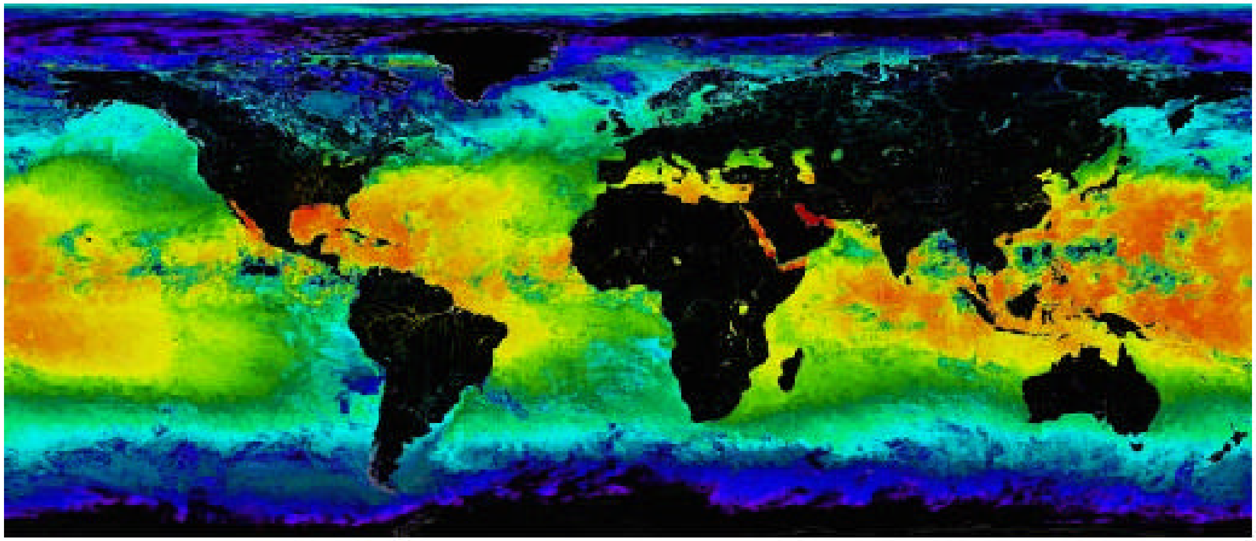
Red=high, blue= low. Glint correction, but no glint mask. Glint pattern shows where data saturate. Pattern near Gulf Stream and in rings reveals wind-current interactions in sfc wave & glint field, and correction is based only on NCEP winds.

Evans/Gordon/Clark



72W
68W
64W
39N
35N
RSMAS

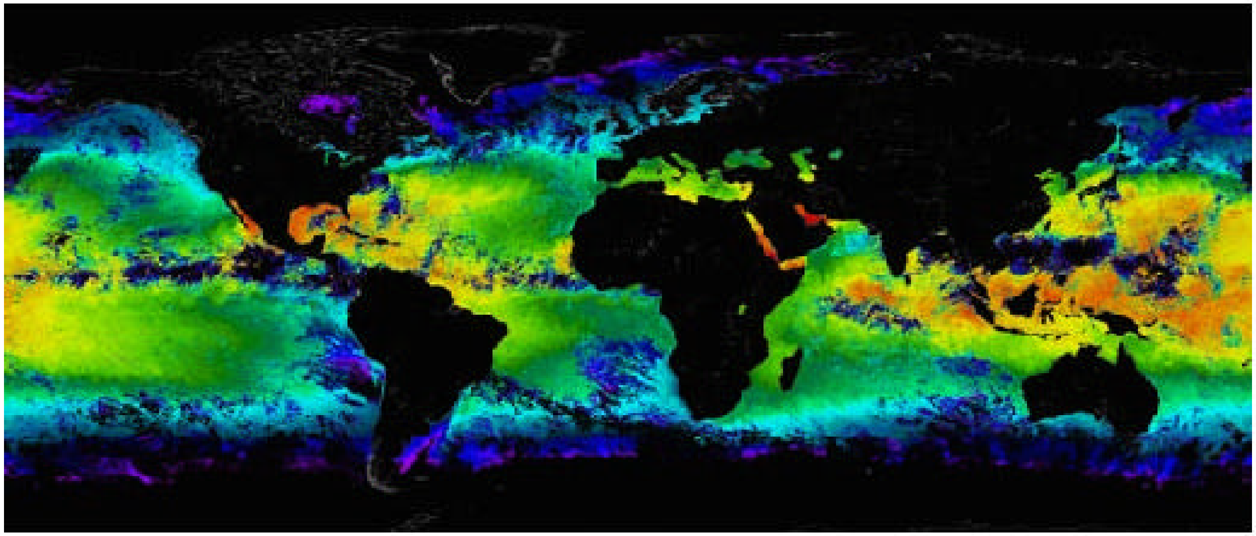
SST - MODIS and AVHRR



MODIS 4 micron
Night SST

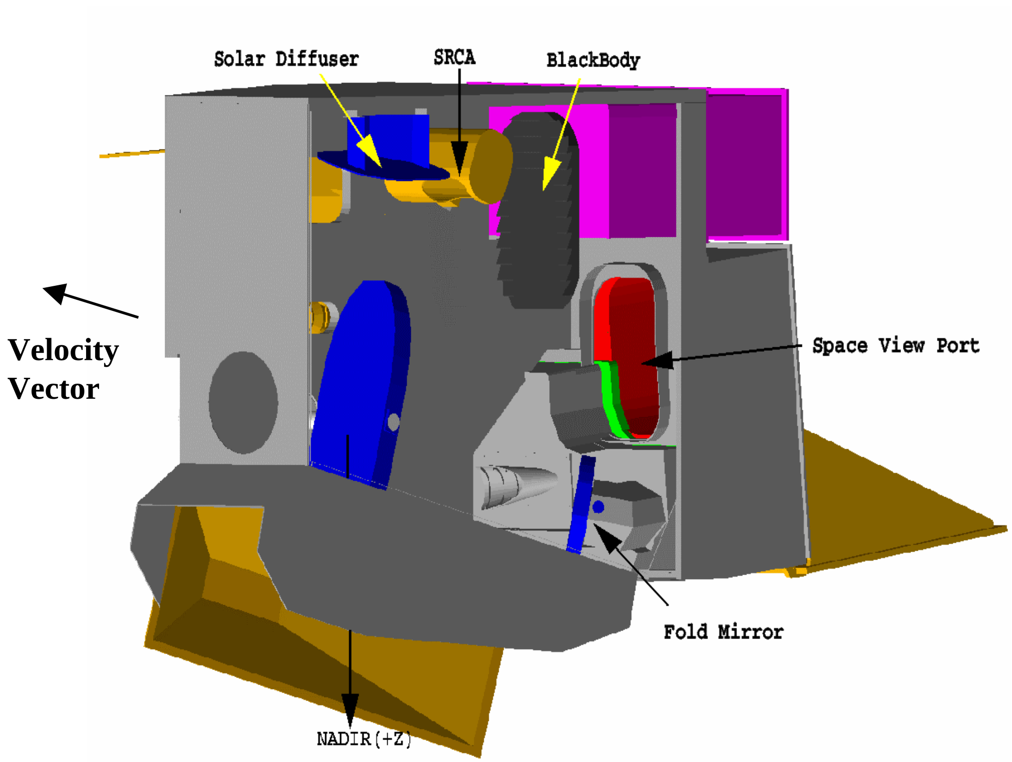
Color scales are not identical, cloud mask is not applied

AVHRR
Night SST

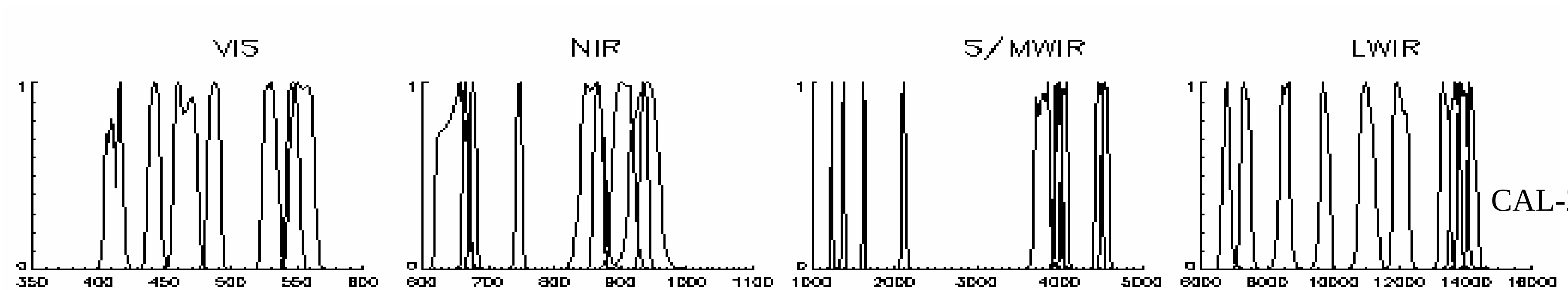


BACKGROUND CHARTS

MODerate Resolution Imaging Spectroradiometer (MODIS)

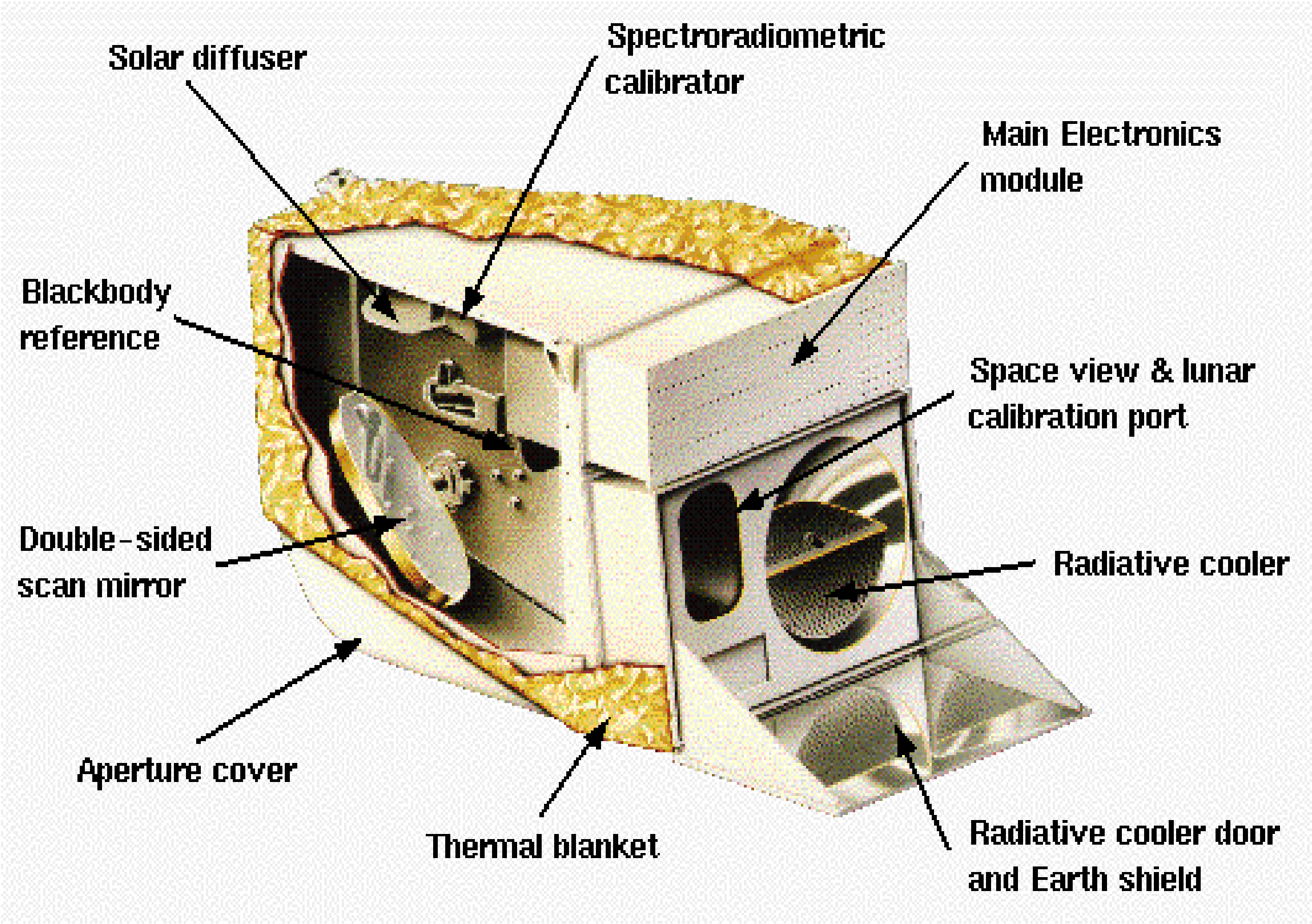


- 36 Spectral Bands (490 detectors) cover the wavelength range from 0.4 to 14.5 μm
- Spatial resolution at nadir: 250, 500 and 1000 meters (depending on band)
- SD/SDSM, SRCA, and Blackbody On-Board Calibrators
- 12 bit (1:4096) dynamic range
- 2-sided Paddle Wheel Scan Mirror scans 2330 km swath



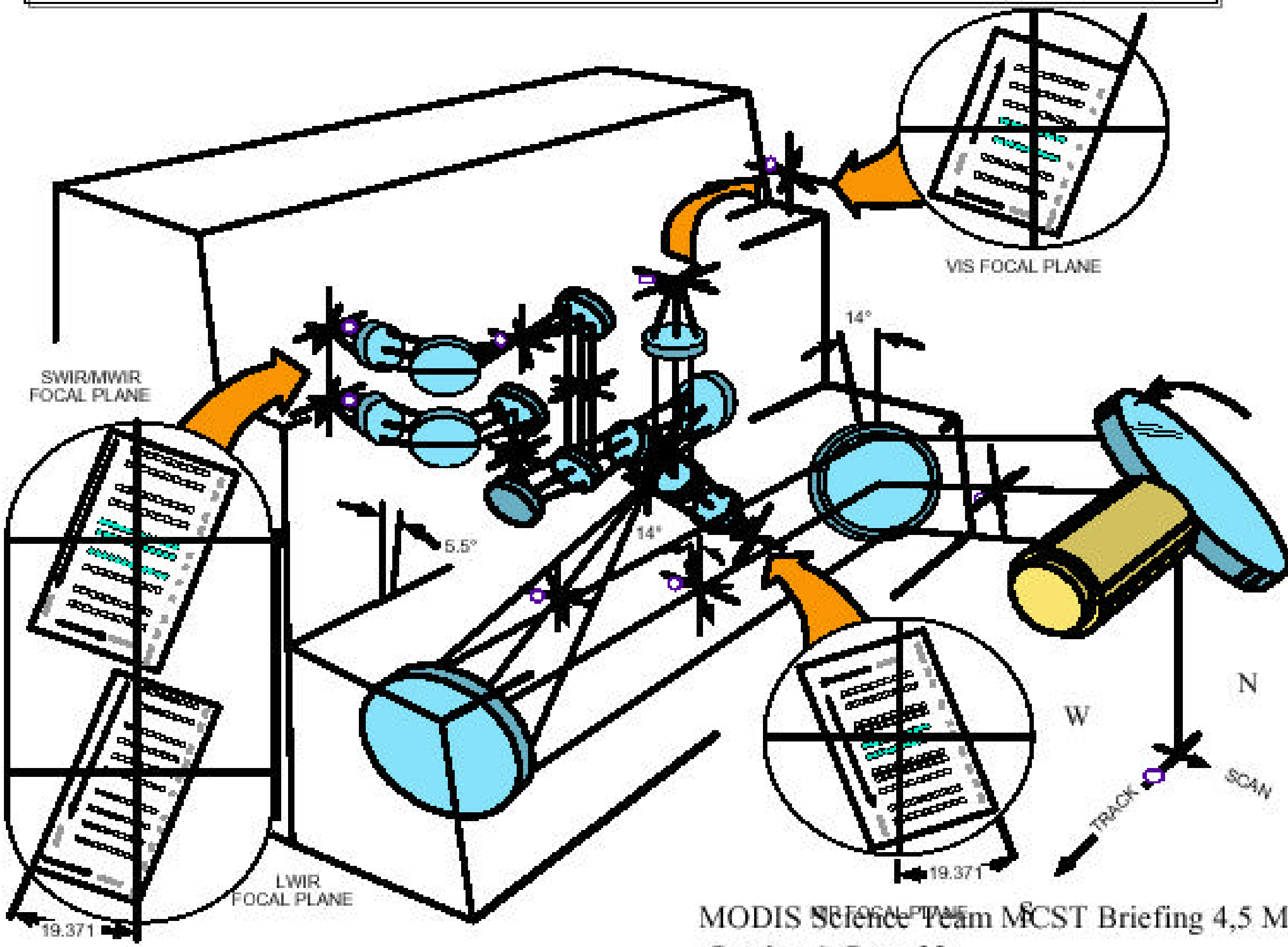
CAL-2

MODIS



BACKGROUND

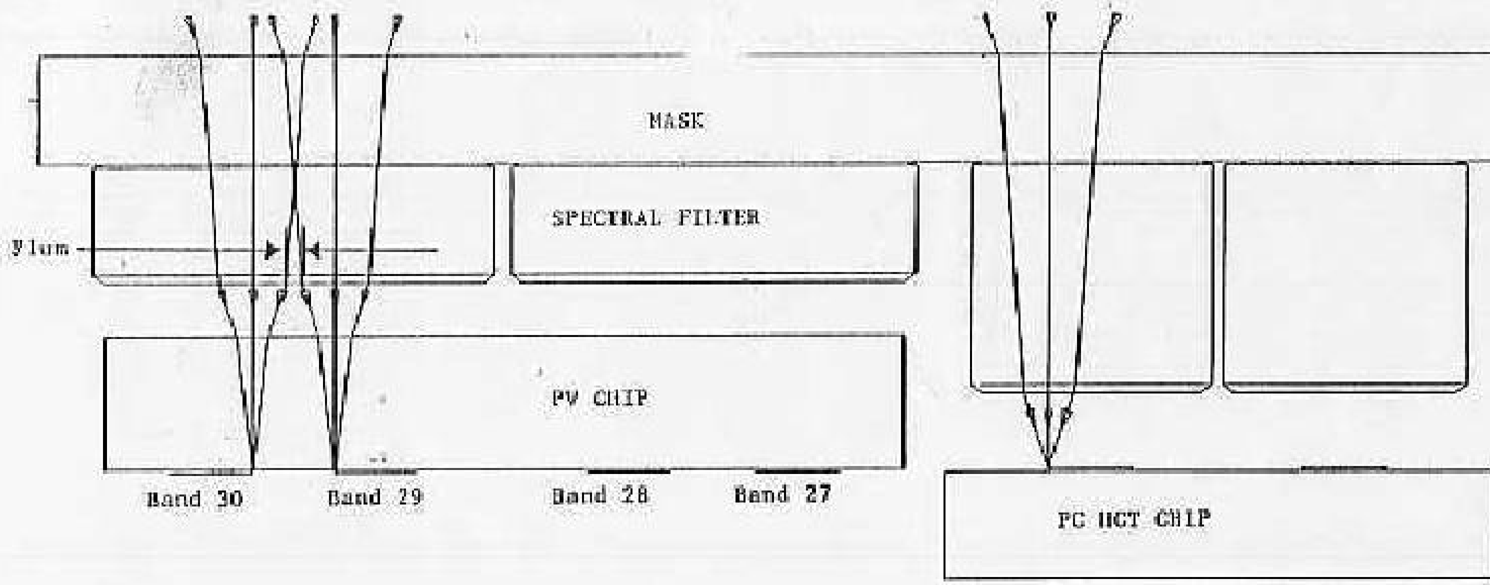
MODIS Optical System



STRAY LIGHT MODELING HELP DEFINE FILTER/MASK GEOMETRY

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary

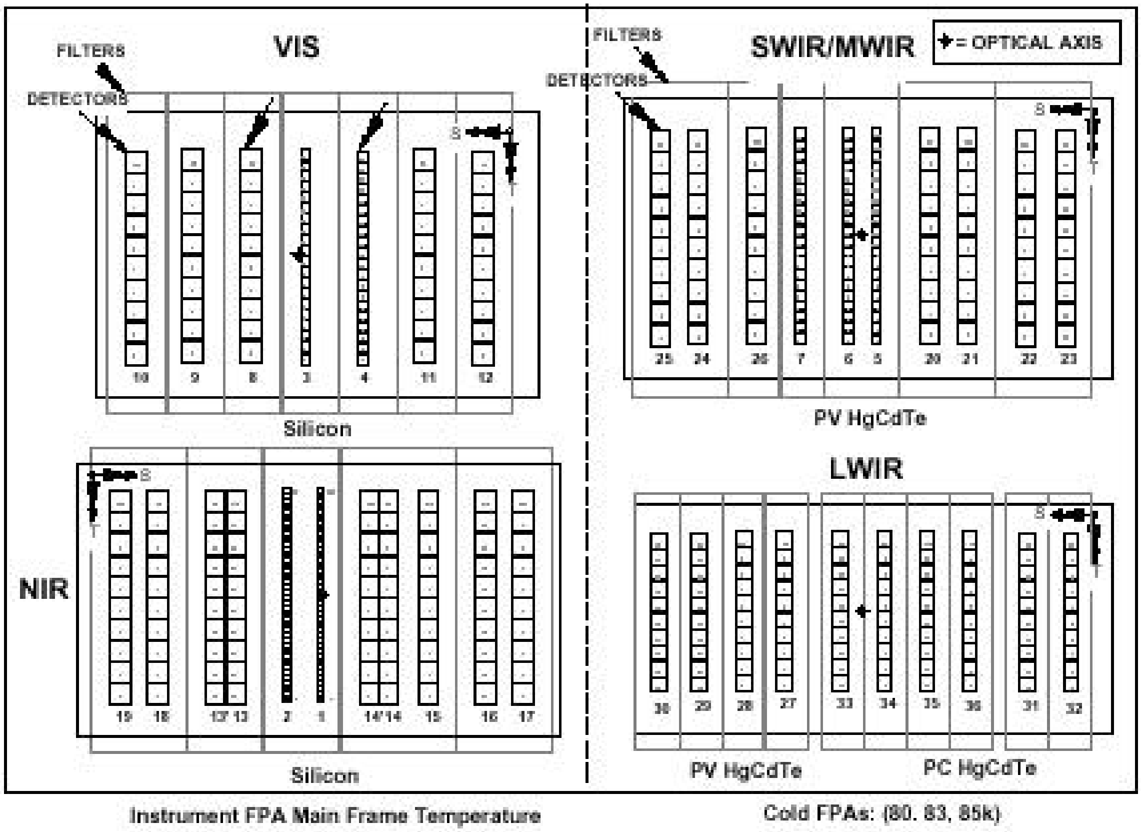


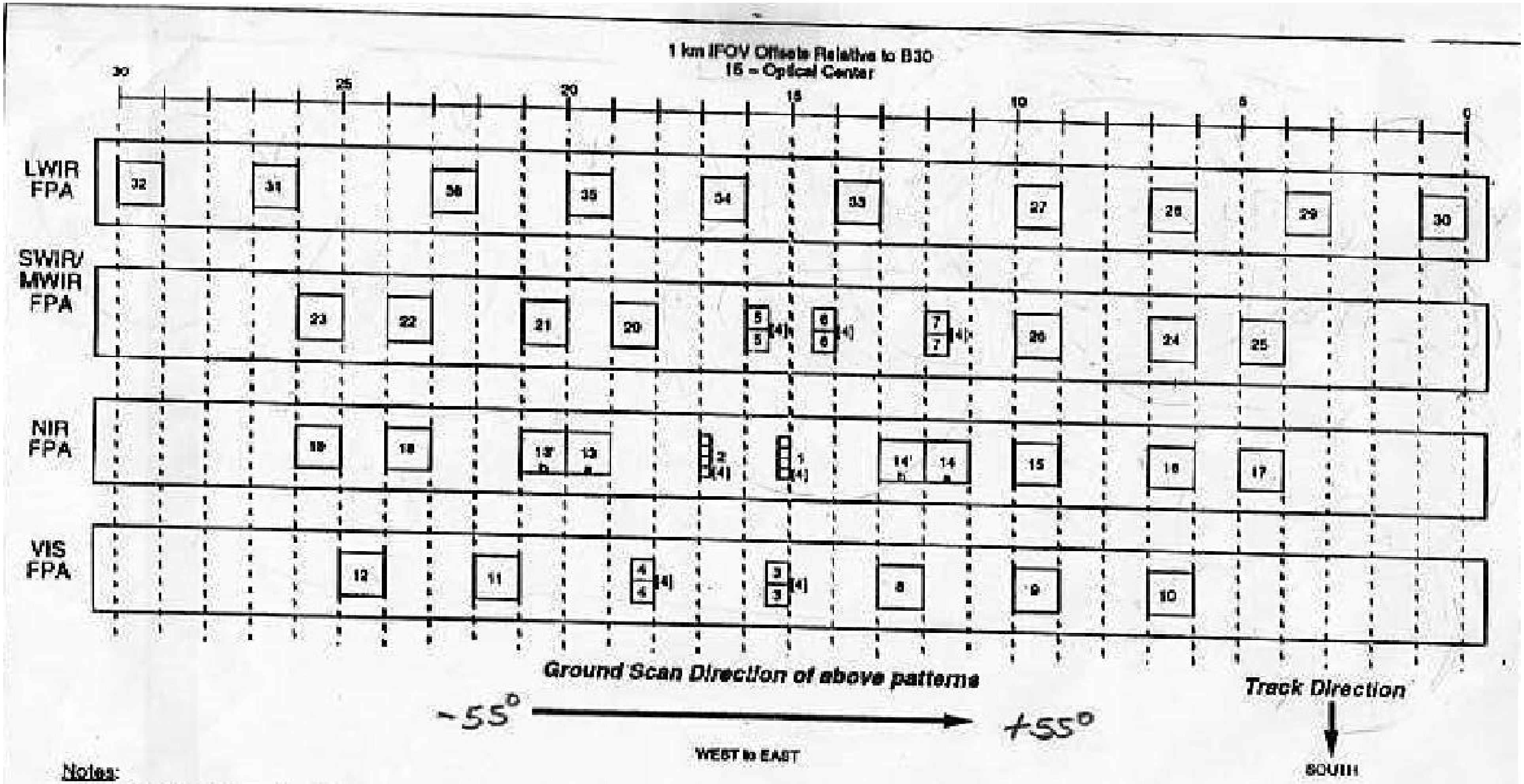
- GEOMETRIC RAYTRACE TO DEFINE GEOMETRY
- MULTIPLE BOUNCES BETWEEN FILTER AND FPA
- OFF-ANGLE REFLECTION AND REFRACTION
- QUANTITATIVE ANALYSIS BASED ON SURFACE REFLECTION, TRANSMISSION AND ABSORPTION PROPERTIES

11/91
91-0908-371A

BACKGROUND

MODIS Focal Plane Layouts



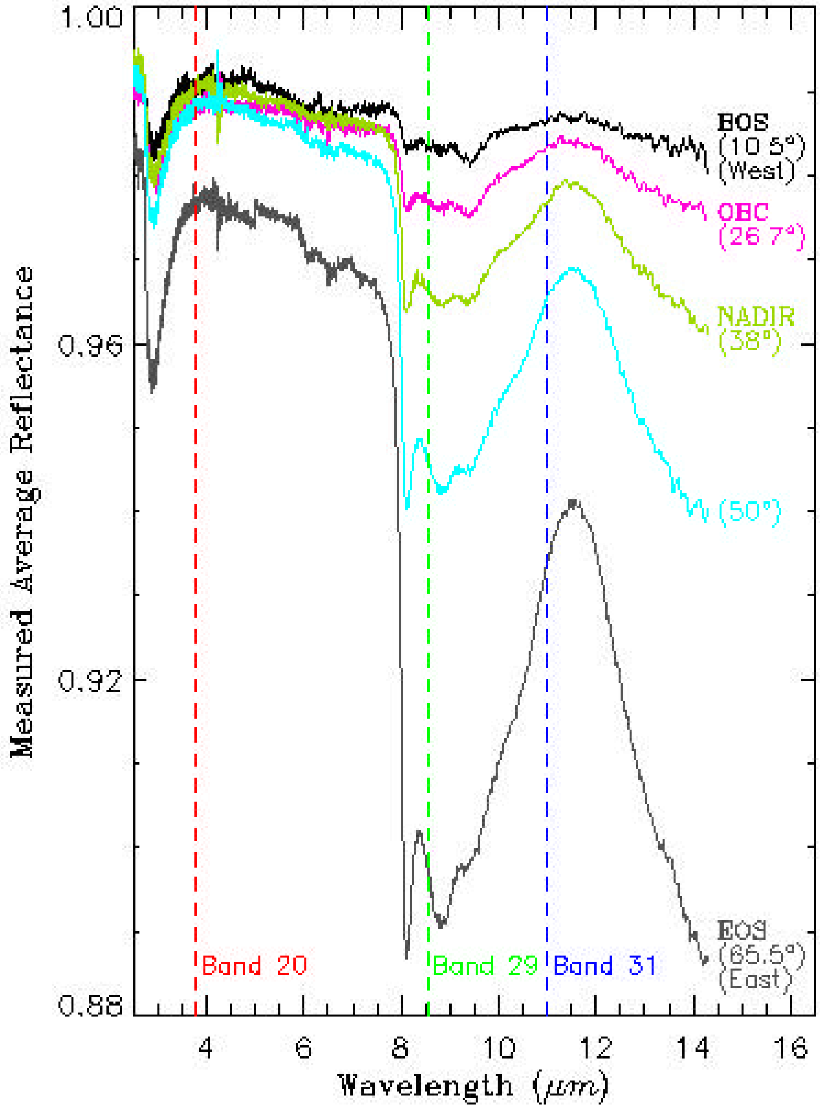


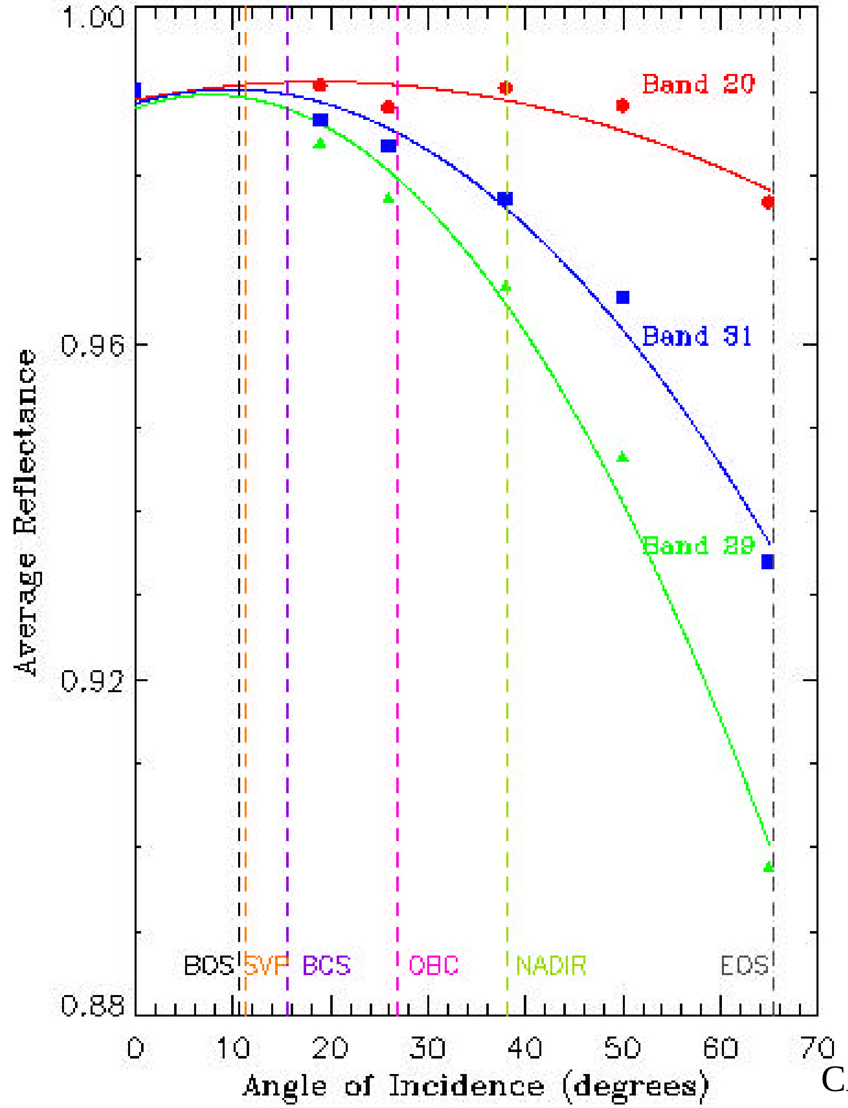
Notes:

1. Band single detector locations are shown in terms of 1 km IFOV offsets from Band 30, which is first band to see a scene. FPA optical center is at IFOV 15.
2. Ground scan direction of projected pattern is to the right (west to east). FPA's have false vertical separation to clarify individual FPA extent.
3. During one 1km sample, 250 m Bands 1 & 2 produce 16 samples/each and 500 m Bands 3-7 produce 4 samples/each.
4. The formatter assembles a science packet with bands aligned by the depicted offsets to view a common ground sample. This requires the collection of 30 frames of data before all bands have observed the same ground sample.
5. Science packet locations for TDI Bands 13, 13' and 14, 14' will be at first sample location of 13 and 14. High and low gain data is provided for Band 13 and Band14. Bands 27-30 are sampled 4X, but single sample is sent to ground.

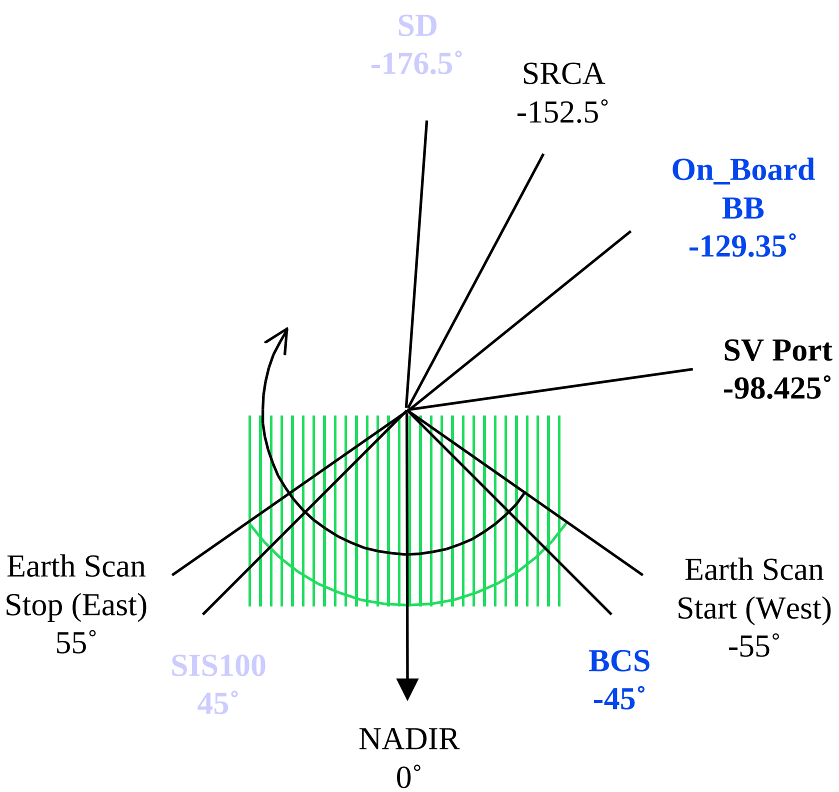
BACKGROUND

Lincoln Laboratory Measured Scan Mirror Average Reflectance

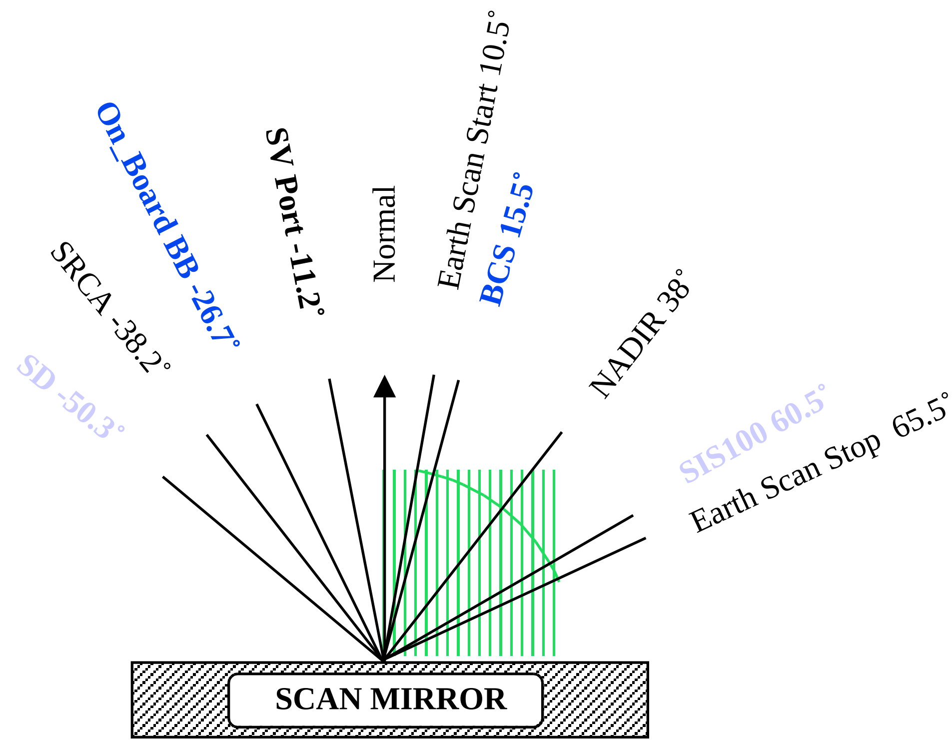




Principal Scan Angles Mapped to Scan Mirror Angles of Incidence

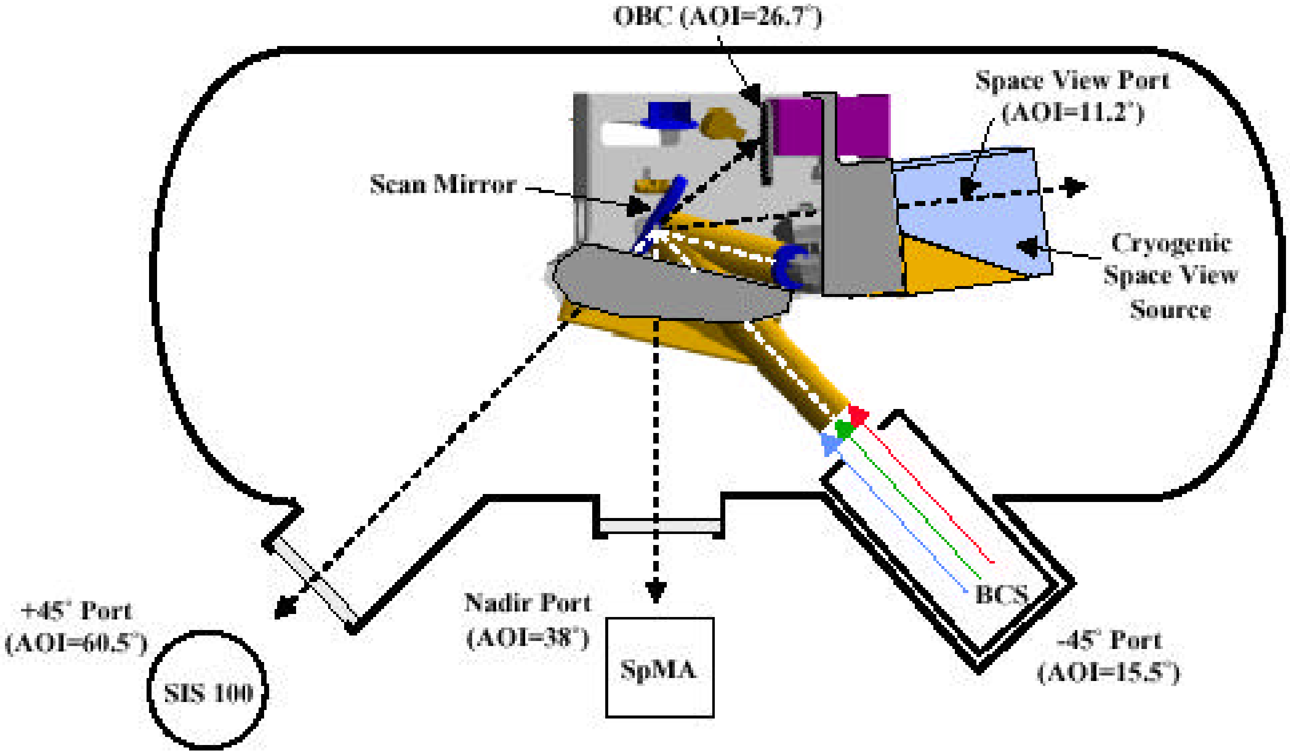


Principal Scan Angles
(Earth View: -55˚ to 55˚)



Angles of Incidence
(Earth View: 10.5˚ to 65.5˚)

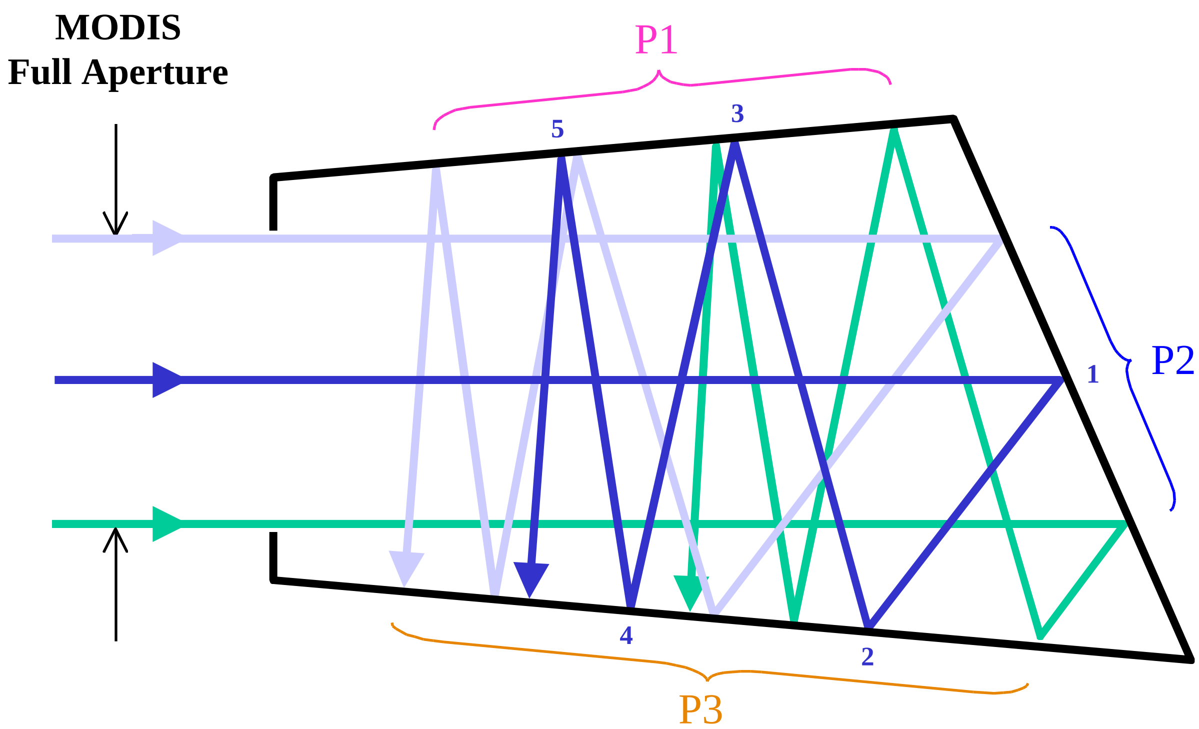
Thermal Vacuum Configuration for MODIS Pre-launch Calibration



Calibrations performed at:

- 3 instrument temperatures (260, 270, and 280K)
- 3 cold focal plane temperatures (83, 85, and 88K)
- 21 BCS levels (170K to 340K); many SIS-100 lamp configurations

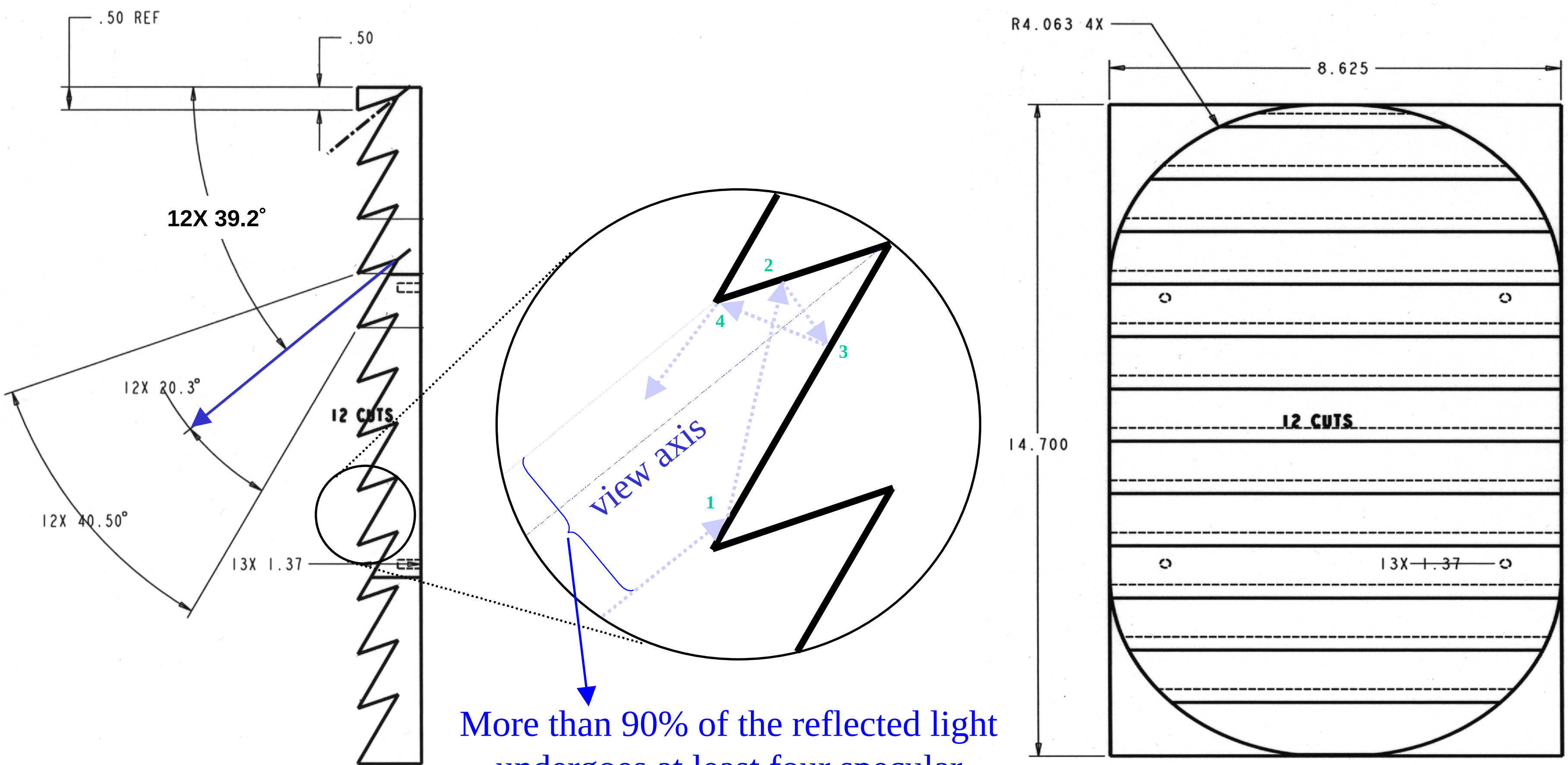
Blackbody Calibration Source (BCS)



$$L_{BCS} = W_{P1} \cdot L(\lambda, T_{P1}) + W_{P2} \cdot L(\lambda, T_{P2}) + W_{P3} \cdot L(\lambda, T_{P3})$$

BCS Trapezoid Configuration Achieves > 0.9998 Emissivity (From SBRS)

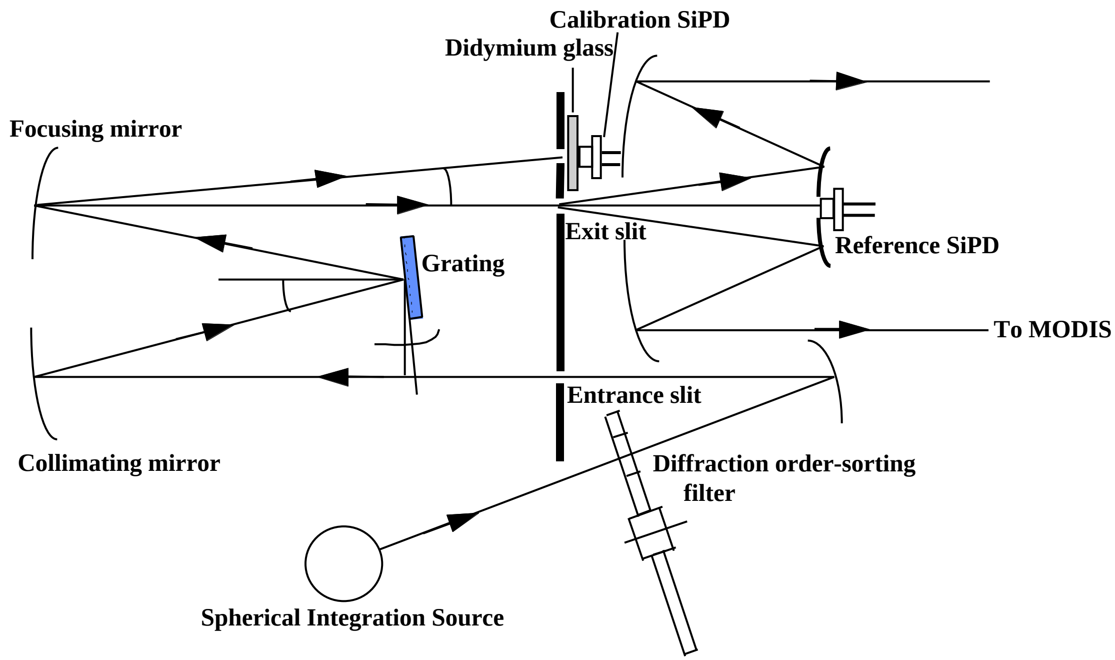
The MODIS On-Board Calibrator (OBC) Blackbody



More than 90% of the reflected light undergoes at least four specular reflections to achieve > 0.992 emissivity

Dimensions: Inches

Spectro-Radiometric Calibration Assembly -- SRCA



BACKGROUND

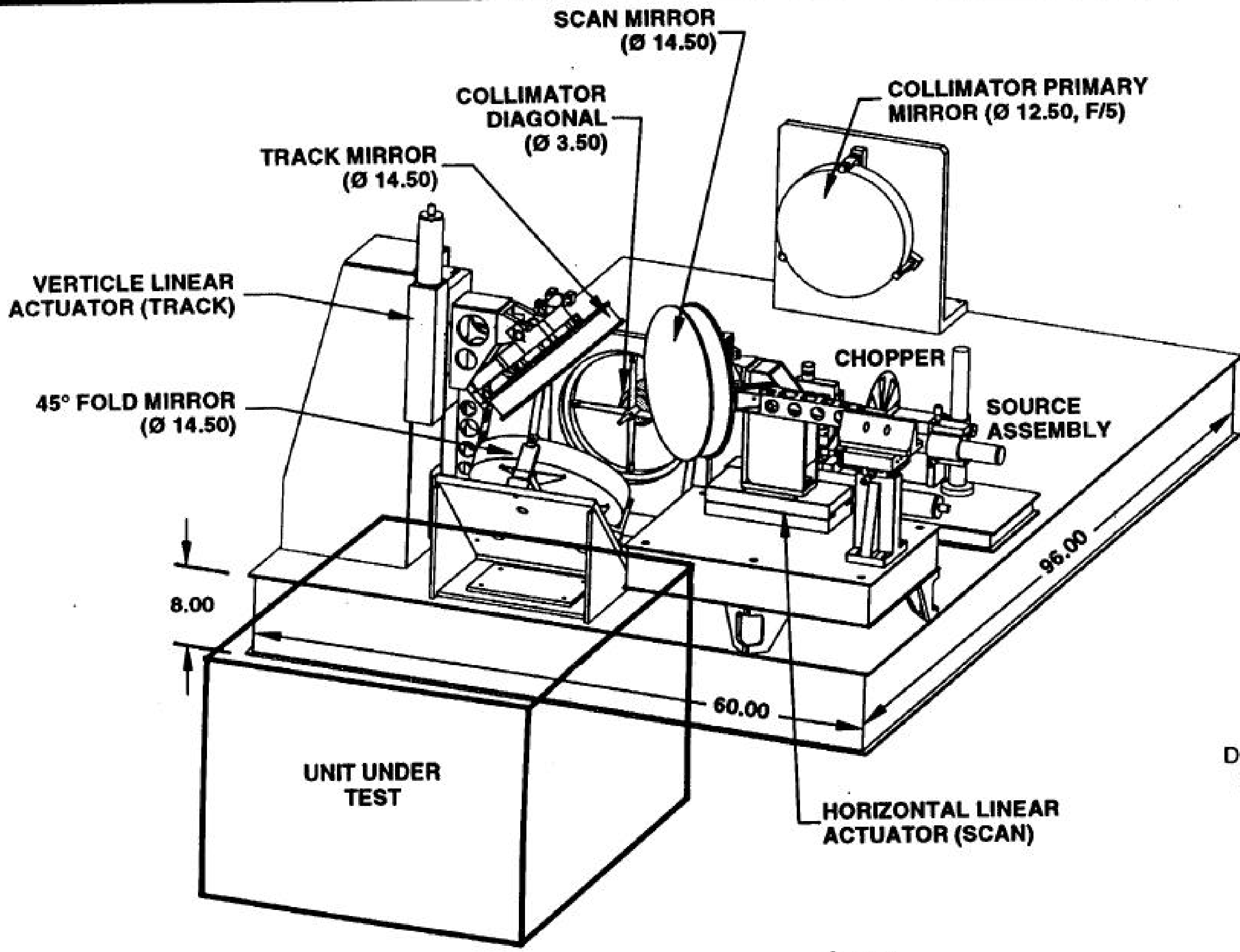
SPATIAL CHARTS

SPATIAL

- Principle Test Equipment
  - Integration and Alignment Collimator system (IAC)
- Test Issues & Concerns
  - Positioning of bands along focal plane based on optimization of science for co-registration
  - Potential thermal and temporal variability of co-registration (in FM1 T/V)
  - Spectral leaks, cross-talks, etc, have spectral/temporal/ spatial weighting functions that need to be applied
  - Bands 1-7 are super-sampled; super-frame 1 in Bands 5/7 sampled same time as super-frame 2 in Band 6
  - Minor IFOV non-compliance
  - Boresight alignment accuracy & knowledge waved from 108 & 90 arcsec to 300 arcsec 3-axes, 3-σ

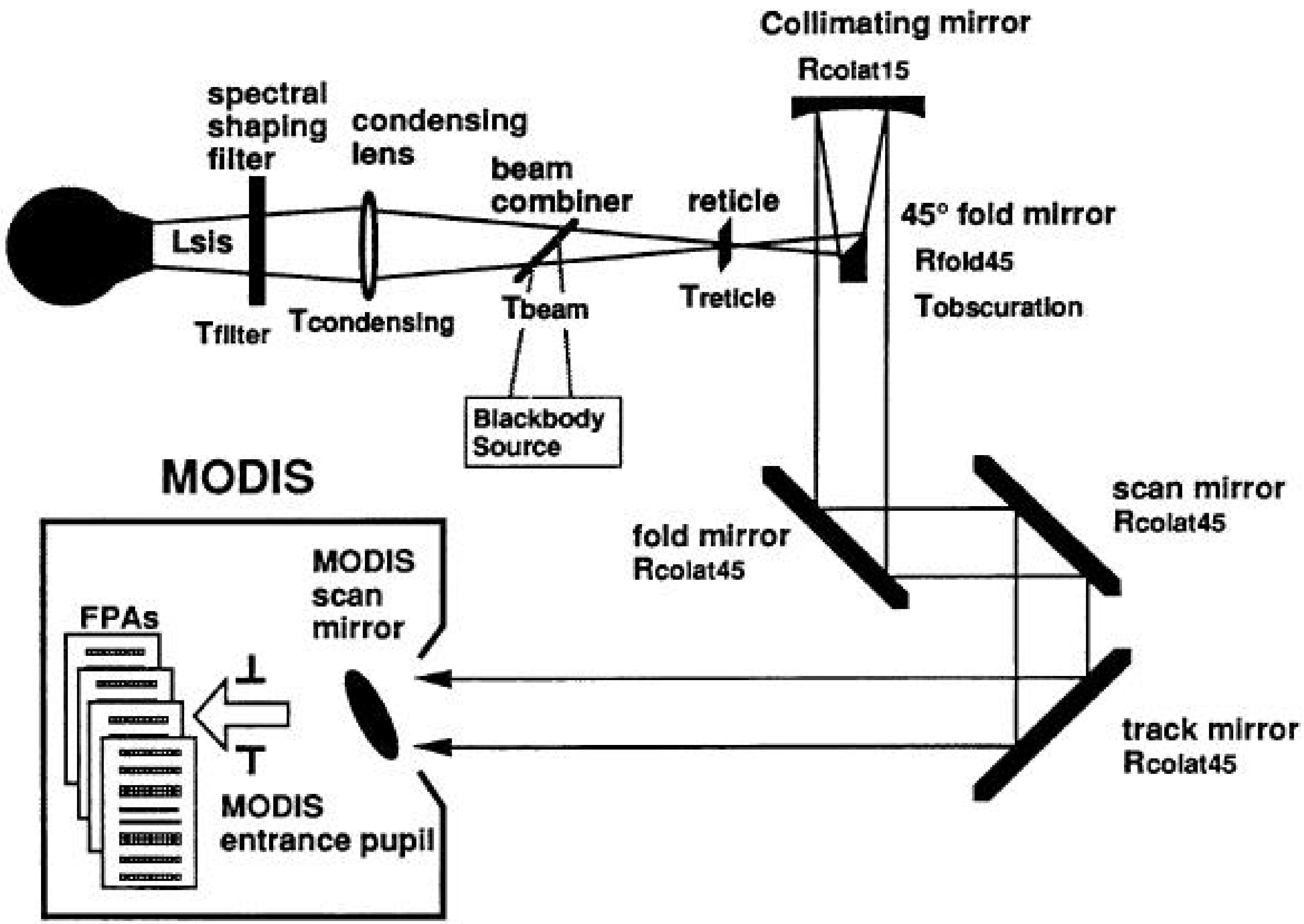
INTEGRATION AND ALIGNMENT COLLIMATOR DESIGN

HUGHES
SANTA BARBARA RESEARCH CENTER
a subsidiary



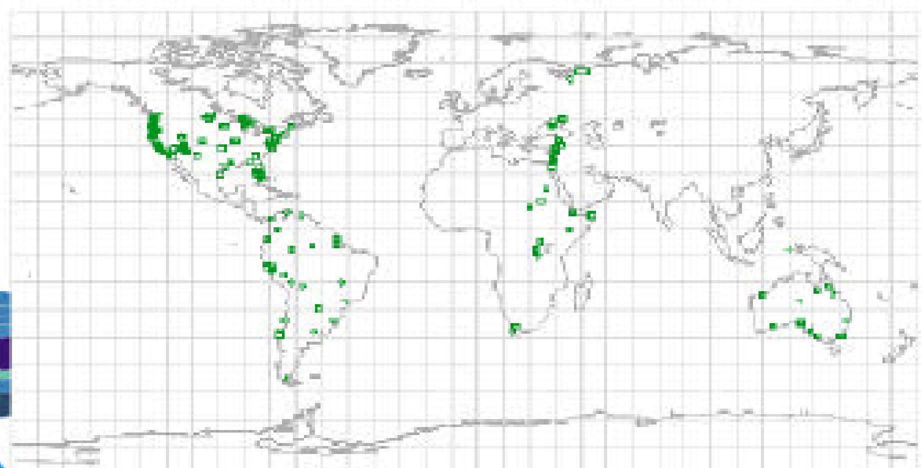
DIMENSIONS
IN INCHES

INTEGRATION AND ALIGNMENT COLLIMATOR



MODIS GEOLOCATION GOALS (R.WOLFE/MODIS SDST)

- Geolocation accuracy specification is 300 m (2 _) and goal is 100 m (2 _) at nadir
- Geolocation goal driven by Land 250 m change product requirements



Global distribution of Ground Control Points

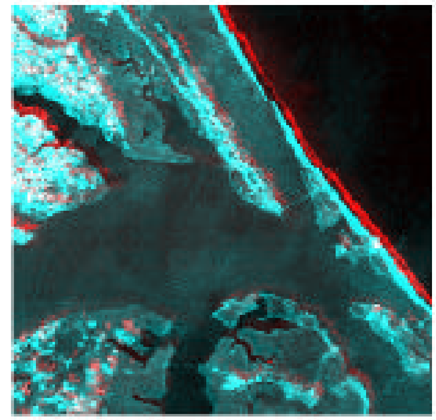
← Land: 550 CPs from 110 TM Scenes

Ocean: 4600 island points from SeaWifs library

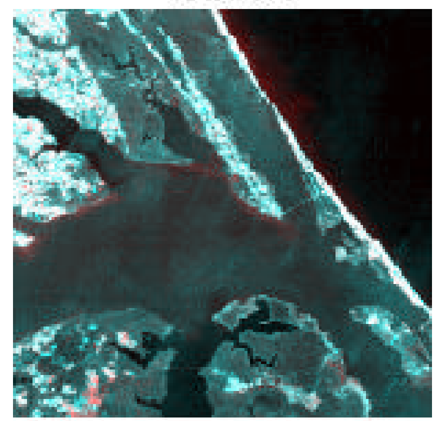
MODIS GEOLOCATION STATUS
(R.Wolfe/MODIS SDST)

- Geolocation and Control point matching programs program are performing well
- At-launch Geolocation error was 1.7 km RMS
  - Biases found in roll (-240 arcsec, -0.8 km at nadir), and pitch (350 arcsec, 1.2 km at nadir)
  - Reduced error to 500 m RMS (March 2000)
- Correction of yaw (134 arcsec) and mirror wedge/tilt angles (39 arcsec, 270 m at nadir)
  - Reduced error to 100 m RMS (200 m 2 _) (June 2000)
- Correction of small remaining biases expected in Dec. 2000
  - Roll (-20 m), Pitch (50 m)
  - Mirror angles (+/- 30 m scan, +/- 10 m track)

At-launch



Current

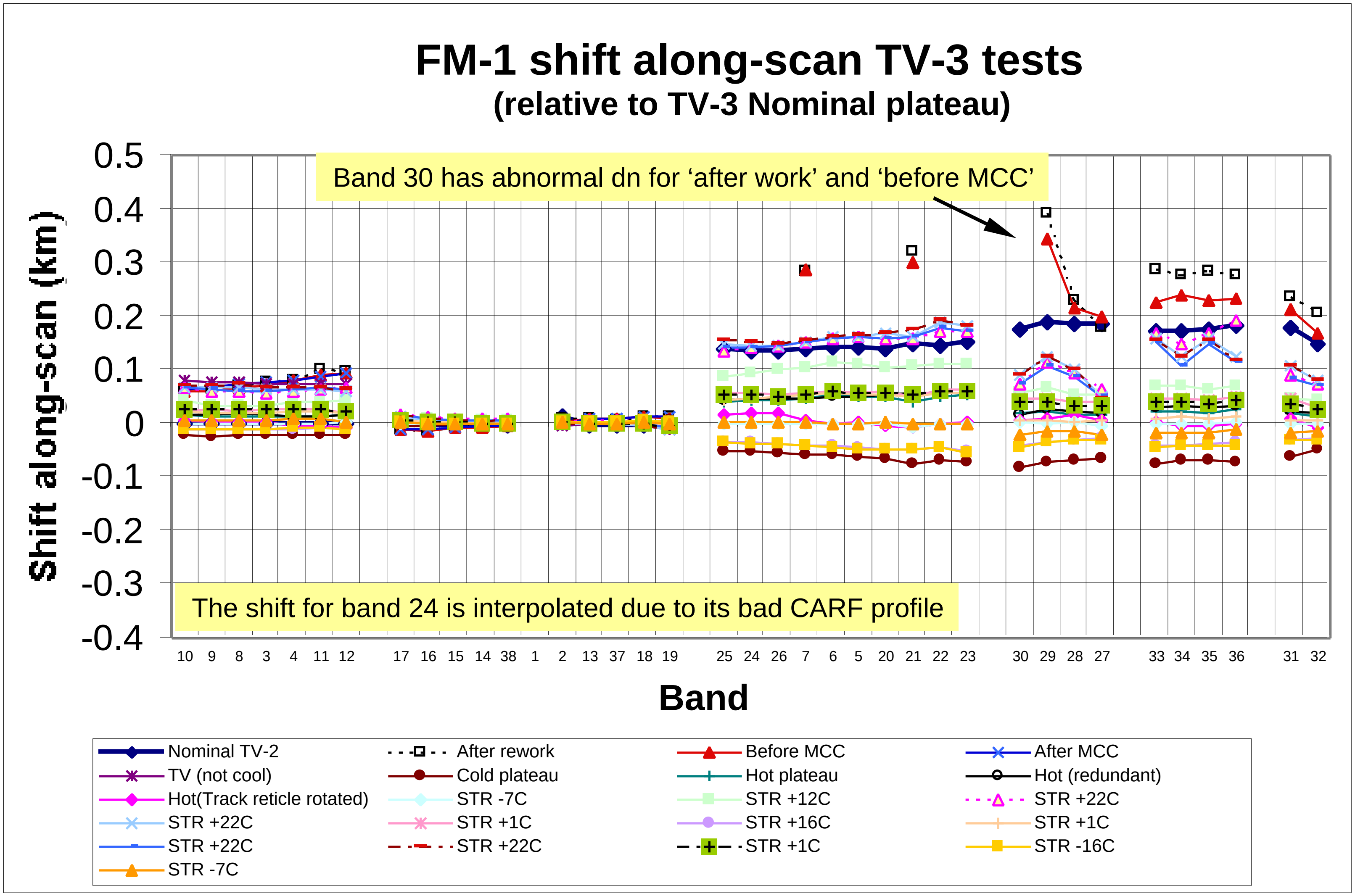


GEOLOCATION NEXT STEPS
(R. Wolfe/MODIS SDST)

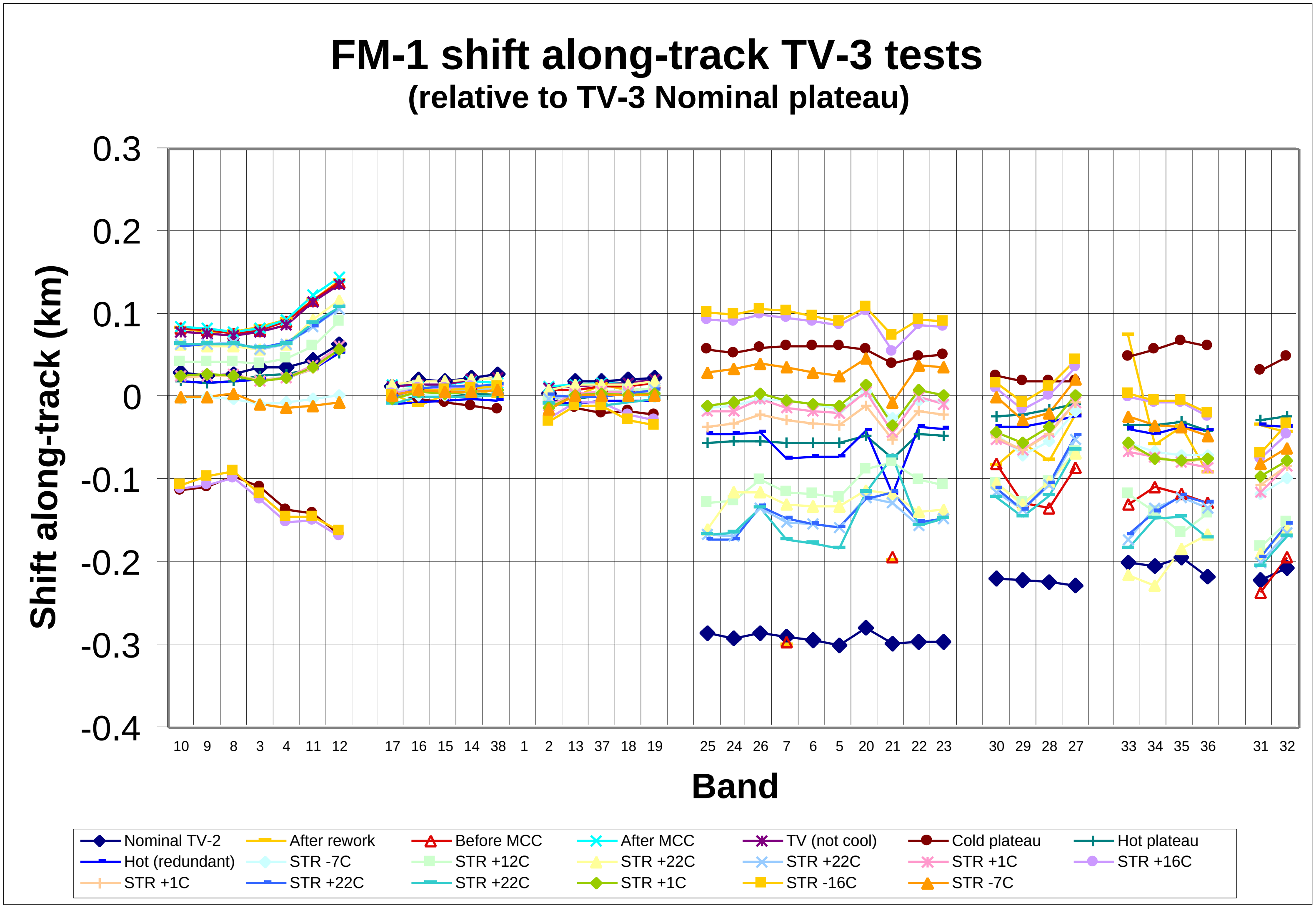
- Further analysis will be performed to characterize along scan mirror motion and remaining biases
  - Currently evaluating effects of change to Side B mirror encoders
- Longer term analysis will look at trends and cyclical variations
  - Will look for dependence on temperature, time on orbit, etc.
- Examine periods near orbit and attitude maneuvers and other events to determine when instrument is outside of accuracy specifications/goals
  - Develop a process to identify the events
  - Operational island matching needed to provide continuous global measurements – analysis of thresholds and use of cloud mask underway
- Evaluate terrain model, correction algorithm
- Examine cross-instrument issues – compare results with MISR and ASTER teams

Expect to reach goal by end of first year

FM-1 SRCA spatial calibration results in TV-3 (3)



FM-1 SRCA spatial calibration results in TV-3 (4)



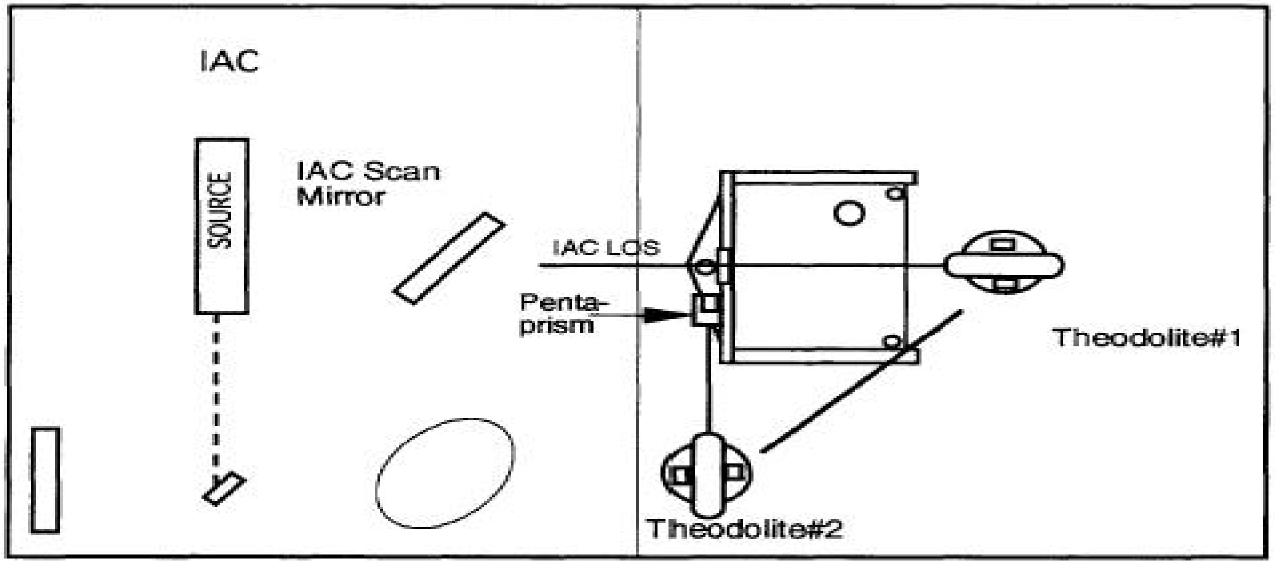


Figure 6. Theodolite #2 Placement

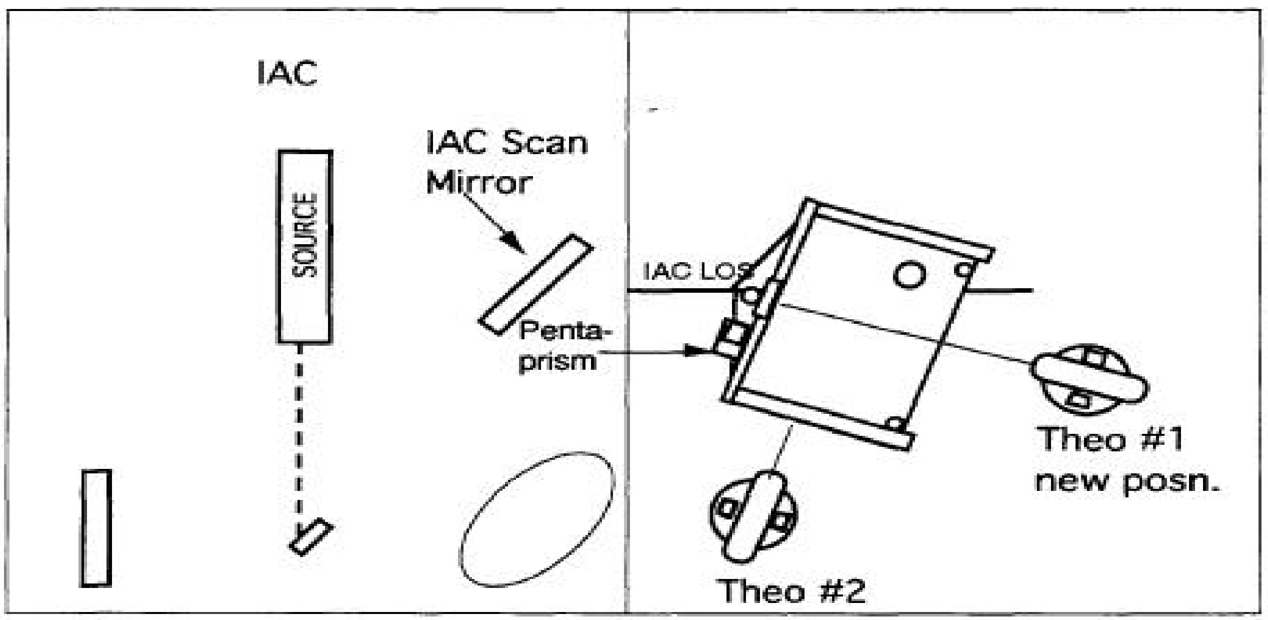


Figure 7. Theodolite #1 new position

Table 4. PF IFOV Results from OBA Data

PF IFOV Results (All Data in Per Cent) From OBA Data									
IFOV Non-Uniformity (Spec±5%)								IFOV Along-Track Tolerance (Spec+0.0%, -6%)	
Band	Ave Track	Min Track	Max Track	Ave Scan	Min Scan	Max Scan		Max Track Tol	Min Track Tol
1	-0.70	-3.80	4.40	4.30	-2.00	1.50		3.70	-4.50
2	-1.20	-4.80	5.70	4.60	-2.20	1.30		4.50	-6.00
3	-0.70	-3.00	1.80	-1.10	-1.10	1.10		1.10	-3.70
4	-0.30	-2.30	2.60	-2.00	-0.30	0.50		2.30	-2.60
5									
6	-1.30	-2.50	2.40	0.50	-2.70	2.10		1.10	-3.80
7	1.70	-2.00	1.60	0.50	-0.50	0.80		3.30	-0.30
8	-0.40	-1.40	1.60	-1.30	-0.90	0.60		0.60	-1.80
9	-0.30	-0.80	0.50	0.90	-1.50	2.50		0.20	-1.10
10	-0.40	-0.70	1.60	2.00	-0.50	0.40		0.60	-1.10
11	-0.20	-0.70	1.30	-1.40	-0.20	0.30		1.10	-0.90
12	-0.40	-0.70	2.40	-2.40	-0.20	0.20		2.80	-1.10
13	0.10	-0.50	0.40	-1.20	-0.30	0.40		0.50	-0.40
14	0.10	-0.60	0.60	-1.00	-0.30	0.60		0.70	-0.80
15	-0.10	-0.90	0.60	3.50	-0.40	0.60		0.50	-1.00
16	0.00	-0.90	0.60	1.00	-0.30	0.30		0.60	-0.80
17	0.00	-0.60	1.10	-0.40	-0.10	0.10		1.10	-0.60
18	0.10	-0.40	0.70	-2.90	-0.30	0.30		0.80	-0.30
19	0.20	-0.80	1.10	-0.30	-0.20	0.30		1.30	-0.40
20	0.60	-1.10	0.90	-0.30	-1.40	0.60		1.50	-0.50
21	-0.30	-1.20	1.40	-2.00	-0.20	0.40		1.10	-1.60
22	0.50	-1.80	0.60	-0.50	-1.40	4.80		1.30	-1.30
23	-0.10	-1.20	0.80	-2.00	-0.40	0.40		0.50	-1.30
24	0.50	-0.70	1.00	0.50	-0.60	0.30		1.50	-0.20
25	0.00	-1.00	0.70	2.80	-1.10	0.00		0.70	-1.00
26	0.60	-0.80	1.10	-0.10	-0.90	0.80		1.70	-0.20
27	1.10	-1.80	1.40	4.80	-0.50	0.80		2.60	-0.50
28	1.40	-1.60	1.10	2.20	-0.70	0.60		2.50	-0.20
29	2.80	-1.60	1.00	3.60	-1.30	0.90		3.60	-1.60
30	1.40	-1.10	0.80	-1.40	-1.20	0.90		2.20	0.30
31	1.10	-3.10	1.60	1.30	-0.90	1.10		2.70	-2.00
32	0.00	-2.30	1.60	-5.70	-1.10	0.70		1.60	-2.30
33	0.30	-2.10	2.40	4.10	-1.10	1.30		2.70	-1.80
34	-0.20	-2.40	2.40	3.50	-0.70	0.90		2.20	-2.60
35	-0.30	-1.90	1.60	2.00	-1.50	1.70		1.20	-3.10
36	1.30	-4.00	2.40	1.00	-1.50	1.30		3.70	-2.70
Bold Indicates Non-Compliance									

Table 21. SCAN Registration Noncompliance SRCA (Fraction of Pixel)

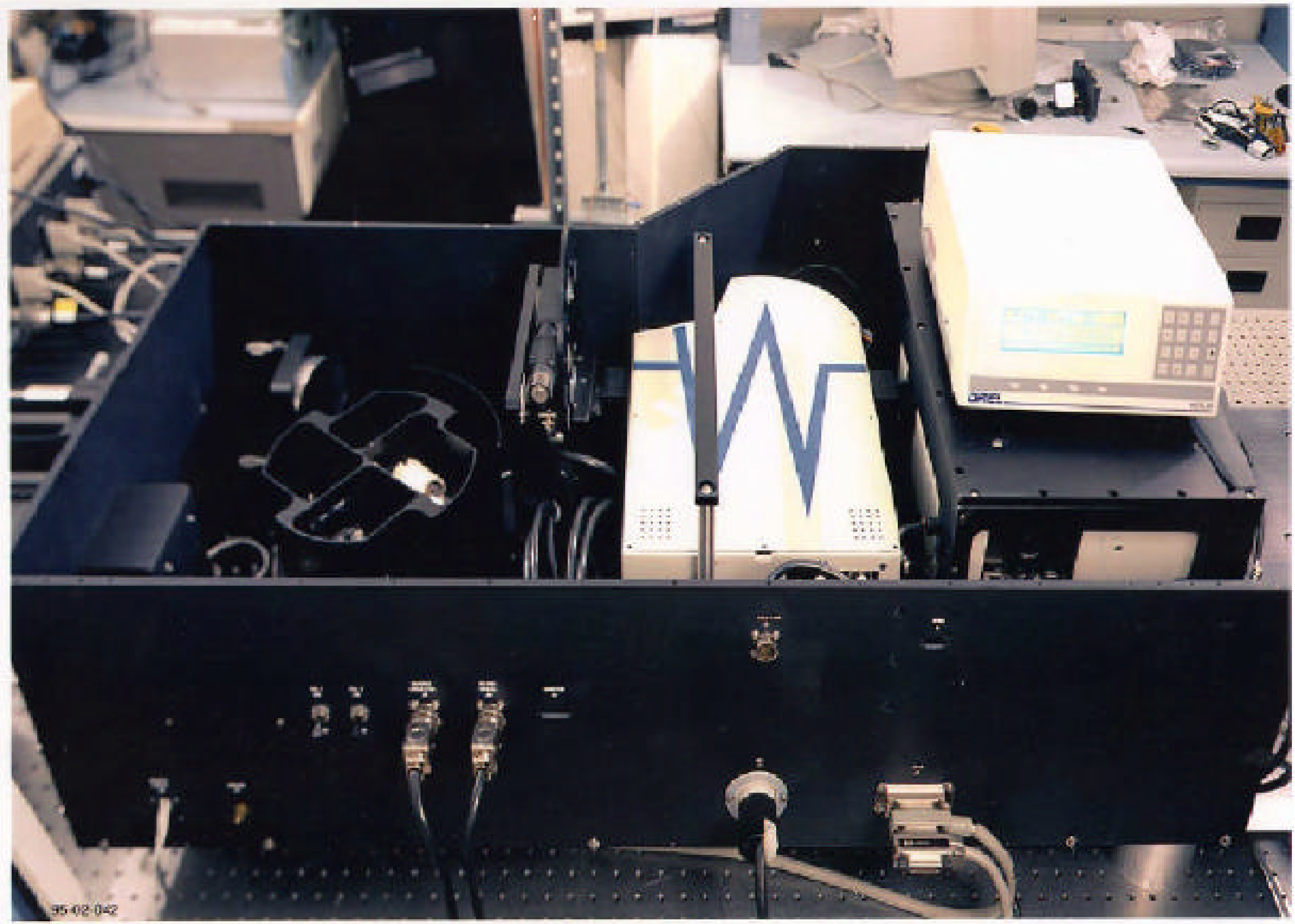
Band	Channel	2nd Bnd	Scan Error
3	20	7	-0.250
4	20	7	-0.269
5	20	7	-0.214
7	20	1	0.263
7	20	2	0.249
7	20	3	0.250
7	20	4	0.269
7	20	5	0.214
12	1	23	-0.217
21	10	1	-0.236
21	10	2	-0.239
21	10	3	-0.237
21	10	4	-0.230
21	10	5	-0.258
21	10	6	-0.278
21	10	7	-0.271
21	10	8	-0.259
21	10	9	-0.247
21	10	10	-0.268
21	10	11	-0.214
21	10	13	-0.257
21	10	14	-0.204
21	10	15	-0.213
21	10	16	-0.208
21	10	17	-0.202
21	10	18	-0.262
21	10	19	-0.278
21	10	20	-0.286
21	10	22	-0.342
21	10	23	-0.324
21	10	24	-0.261
21	10	25	-0.294
21	10	26	-0.227
21	10	27	-0.339
21	10	28	-0.326
21	10	29	-0.322
21	10	30	-0.415
21	10	31	-0.260
21	10	33	-0.262
21	10	34	-0.234
21	10	35	-0.276
21	10	36	-0.335

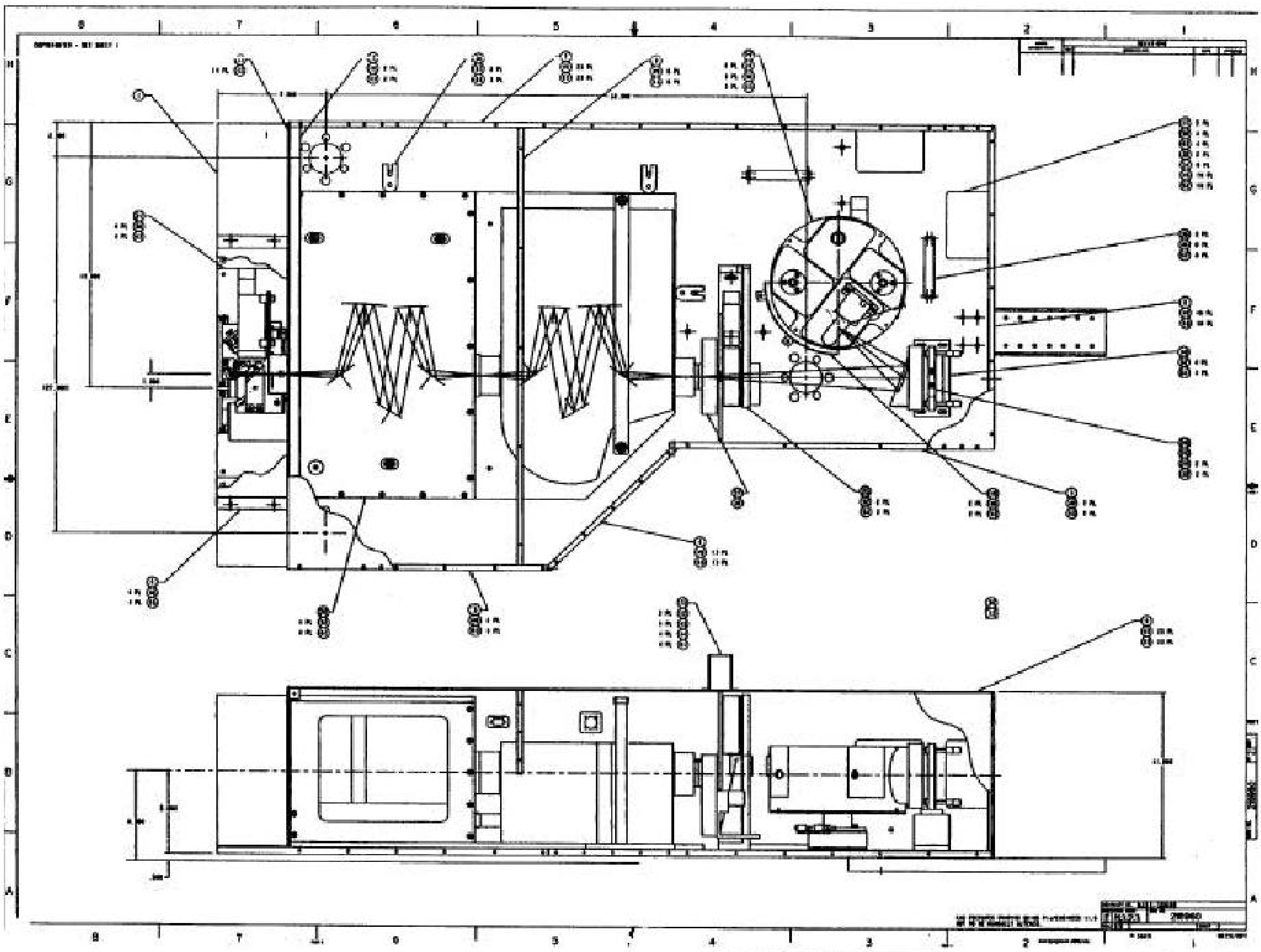
Table 21. SCAN Registration Noncompliance SRCA (Cont'd)
(Fraction of 1 KM Pixel)

30	10	11	-0.201
30	10	12	0.236
30	10	14	0.211
30	10	15	0.202
30	10	16	0.207
30	10	17	-0.213
32	1	18	-0.211
32	1	19	-0.202
32	1	22	-0.214
32	1	23	-0.298
32	1	27	-0.238
32	1	28	-0.218
32	1	29	-0.222
32	1	30	-0.209
32	2	27	-0.231
32	2	28	-0.203
32	2	30	-0.232
32	3	22	-0.236
32	3	27	-0.226
32	3	28	-0.203
32	3	30	-0.231
32	4	27	-0.220
32	4	28	-0.226
32	4	30	-0.240
32	5	27	-0.209
32	5	30	-0.224
32	6	27	-0.224
32	6	30	-0.215
32	7	27	-0.222
32	7	30	-0.208
32	8	27	-0.214
32	8	30	-0.211
32	9	27	-0.207
32	9	30	-0.209
32	10	30	-0.278

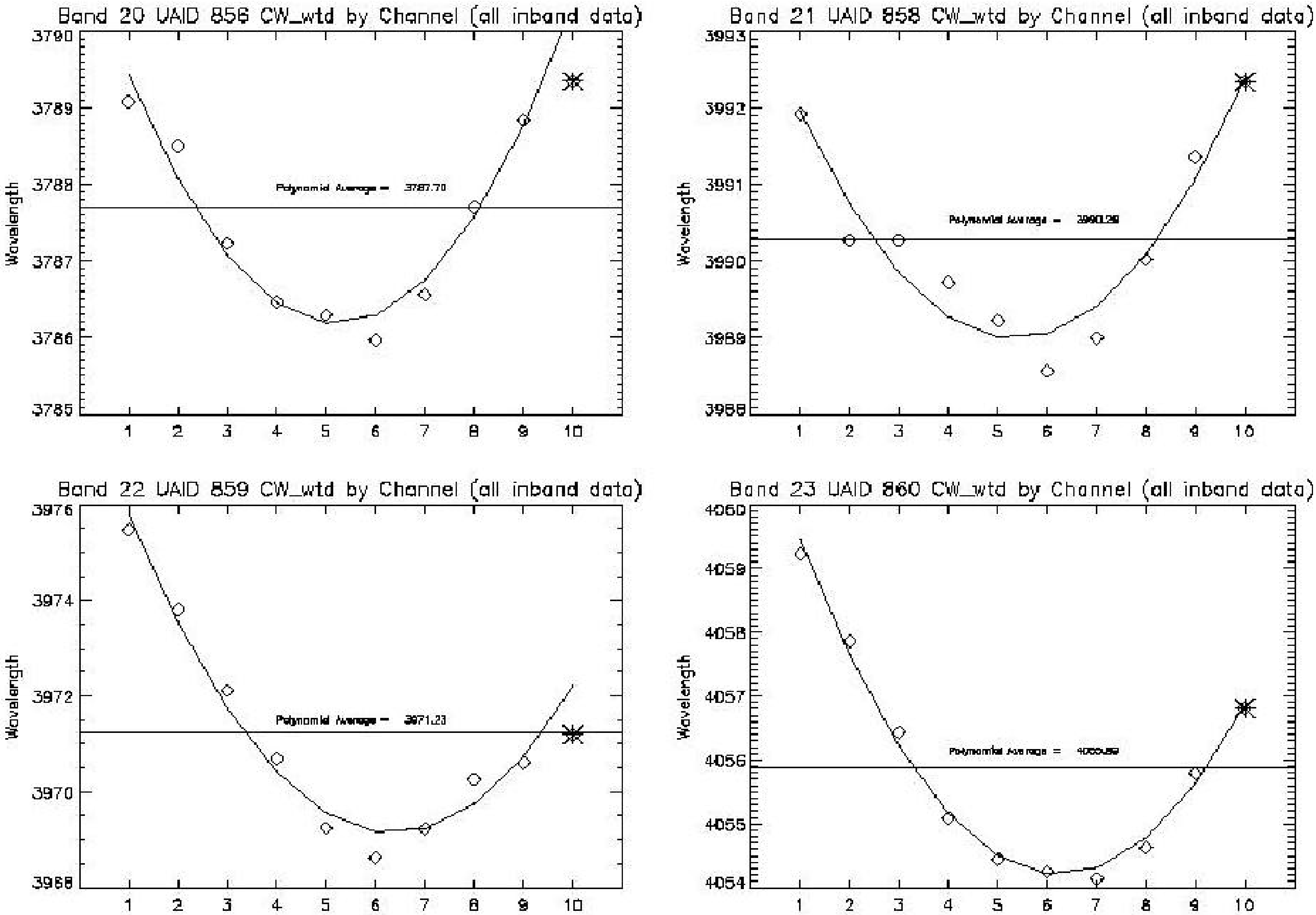
SPECTRAL CHARTS

Spectral Measurement Assembly (SpMA)

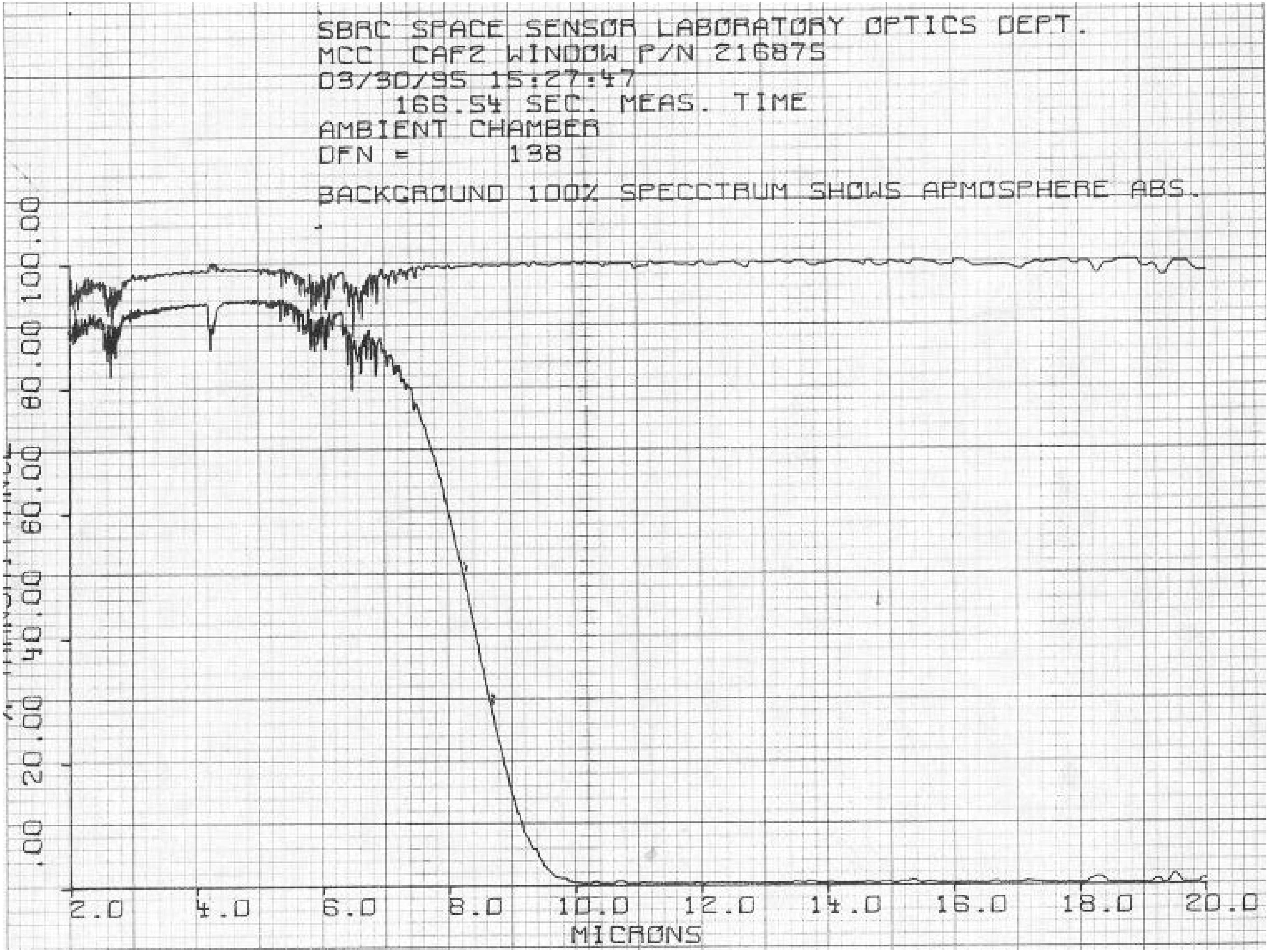


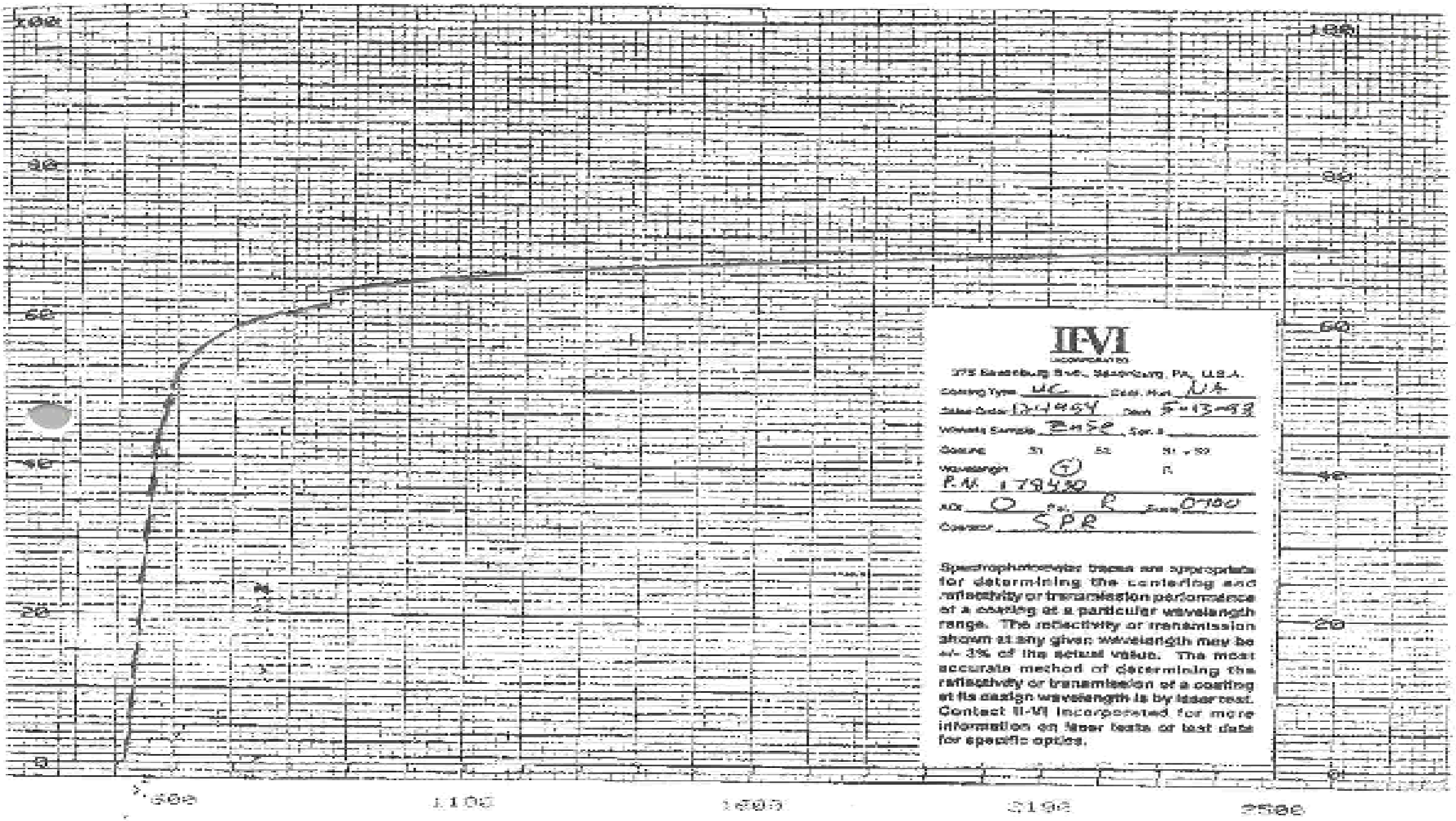


PFM Ambient PC-071



* represent CWL measurements not used to generate the fitted polynomial
-- Average of Fitted Polynomial Points for each Channel


SBRC SPACE SENSOR LABORATORY OPTICS DEPT.
MCC CAF2 WINDOW P/N 216875
03/30/95 15:27:47
166.54 SEC. MEAS. TIME
AMBIENT CHAMBER
DFN = 138
BACKGROUND 100% SPECCTRUM SHOWS APMOSPHERE ABS.
100.00
80.00
60.00
40.00
20.00
.00
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
MICRONS



100
80
60
40
20
0
600
1100
1600
2100
2600
II-VI
P.N. 179430
SPR
Spectrophotometer traces are appropriate for determining the centering and reflectivity or transmission performance of a coating at a particular wavelength range. The reflectivity or transmission shown at any given wavelength may be +/- 3% of the actual value. The most accurate method of determining the reflectivity or transmission of a coating at its design wavelength is by laser test. Contact II-VI Incorporated for more information on laser tests or test data for specific optics.

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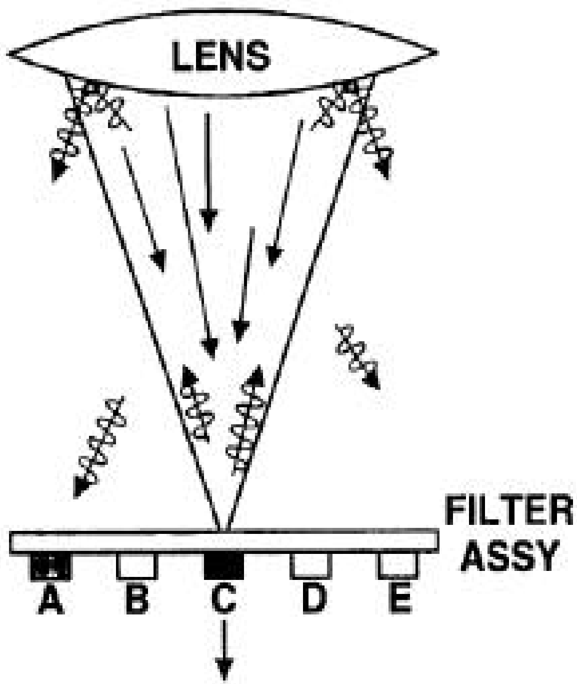
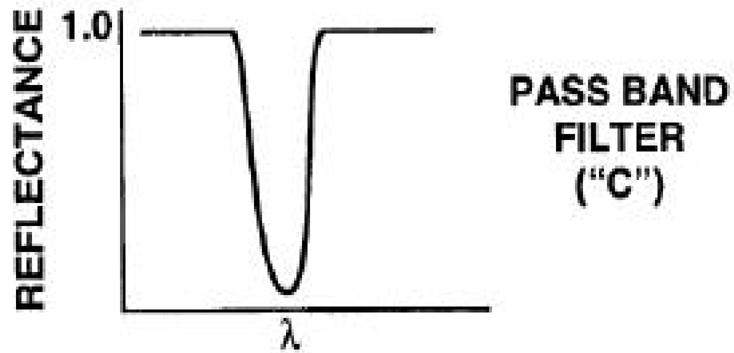
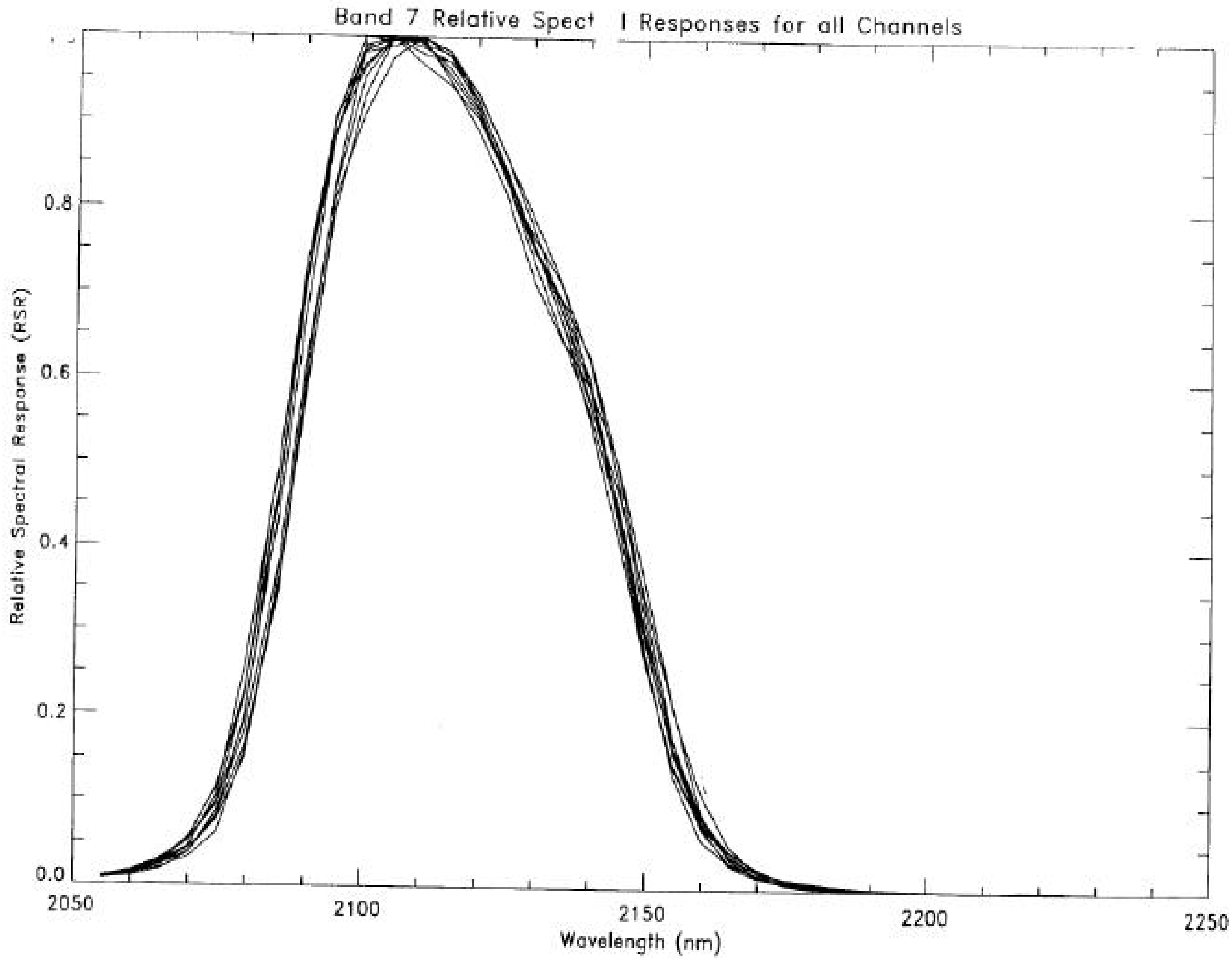
WHAT IS GHOSTING?





- OUT OF BAND ENERGY FOR FILTER "C" IS REFLECTED BACK FROM THE FILTER ASSY. TOWARDS THE OPTICS
- NON PERFECT AR COATINGS ON THE LENSES REFLECTS A SMALL FRACTION BACK TO THE FOCAL PLANE THAT IS WITHIN PASS BAND FOR FILTER "A"

8/93
93-0673-109



Band 7 Relative Spect l Responses for all Channels
Relative Spectral Response (RSR)
0.0
0.2
0.4
0.6
0.8
2050
2100
2150
2200
2250
Wavelength (nm)

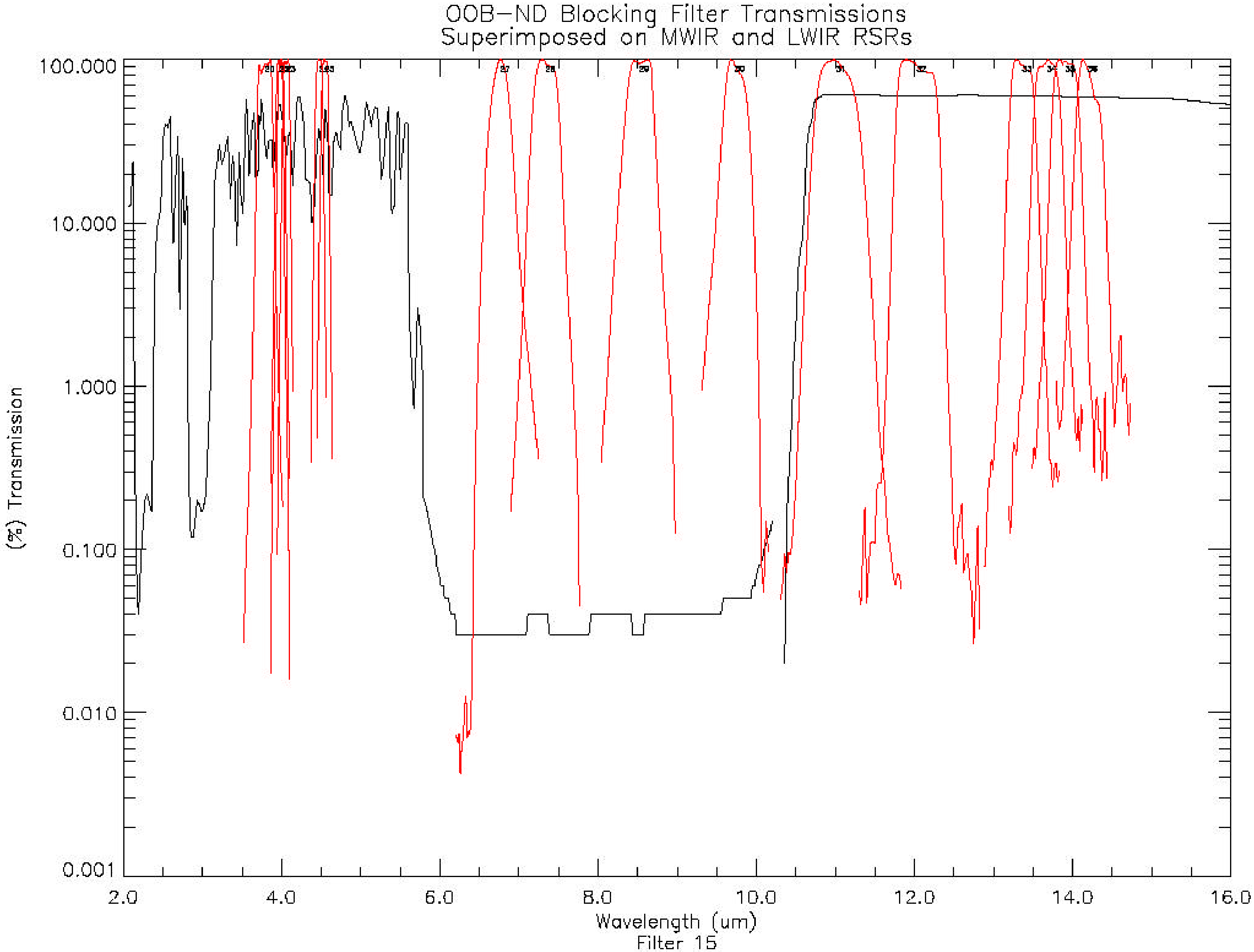
Table 5. Spectral Response Analysis — Specifications Matching Report

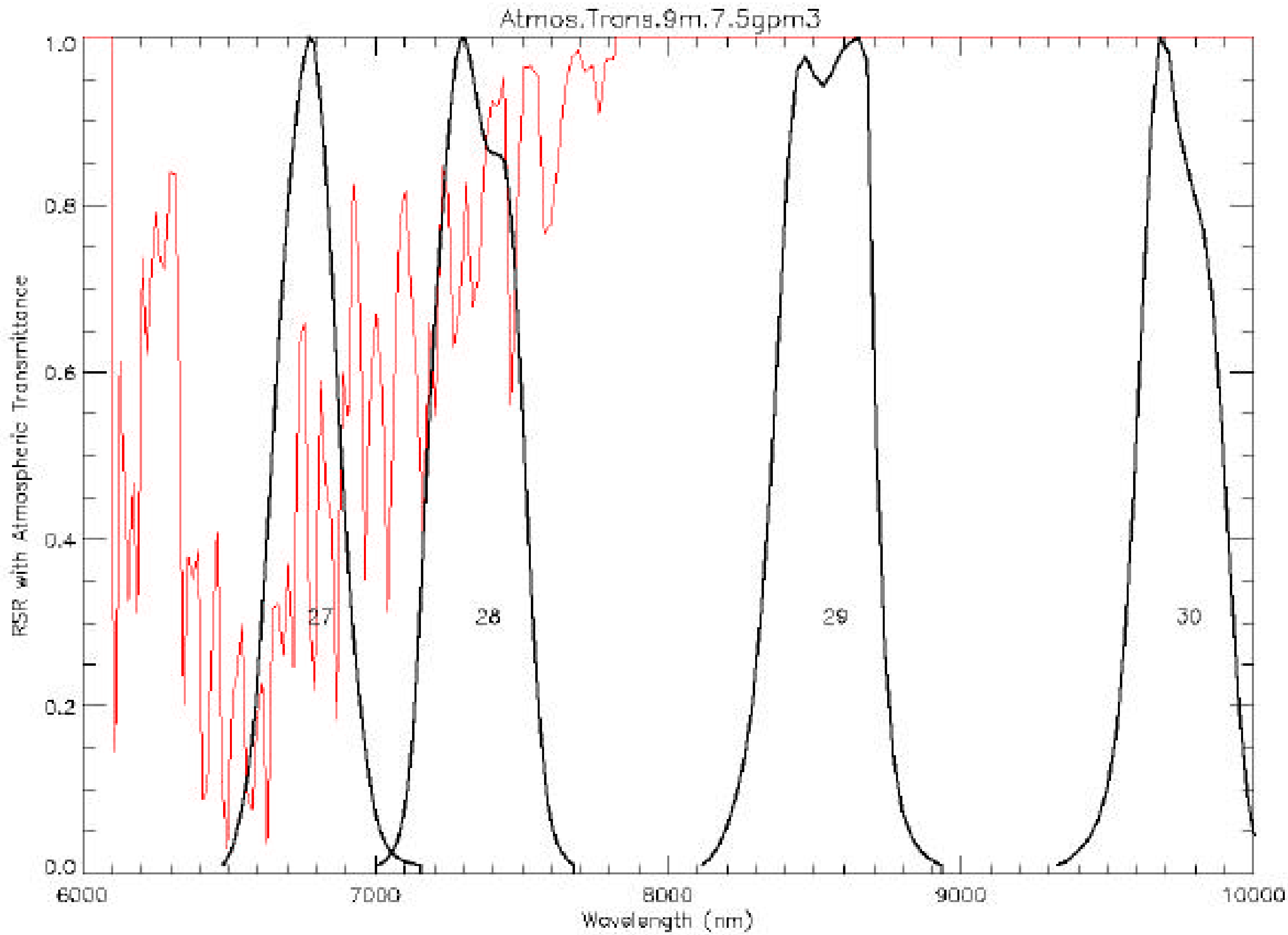
sr.10A   r.rel.spec

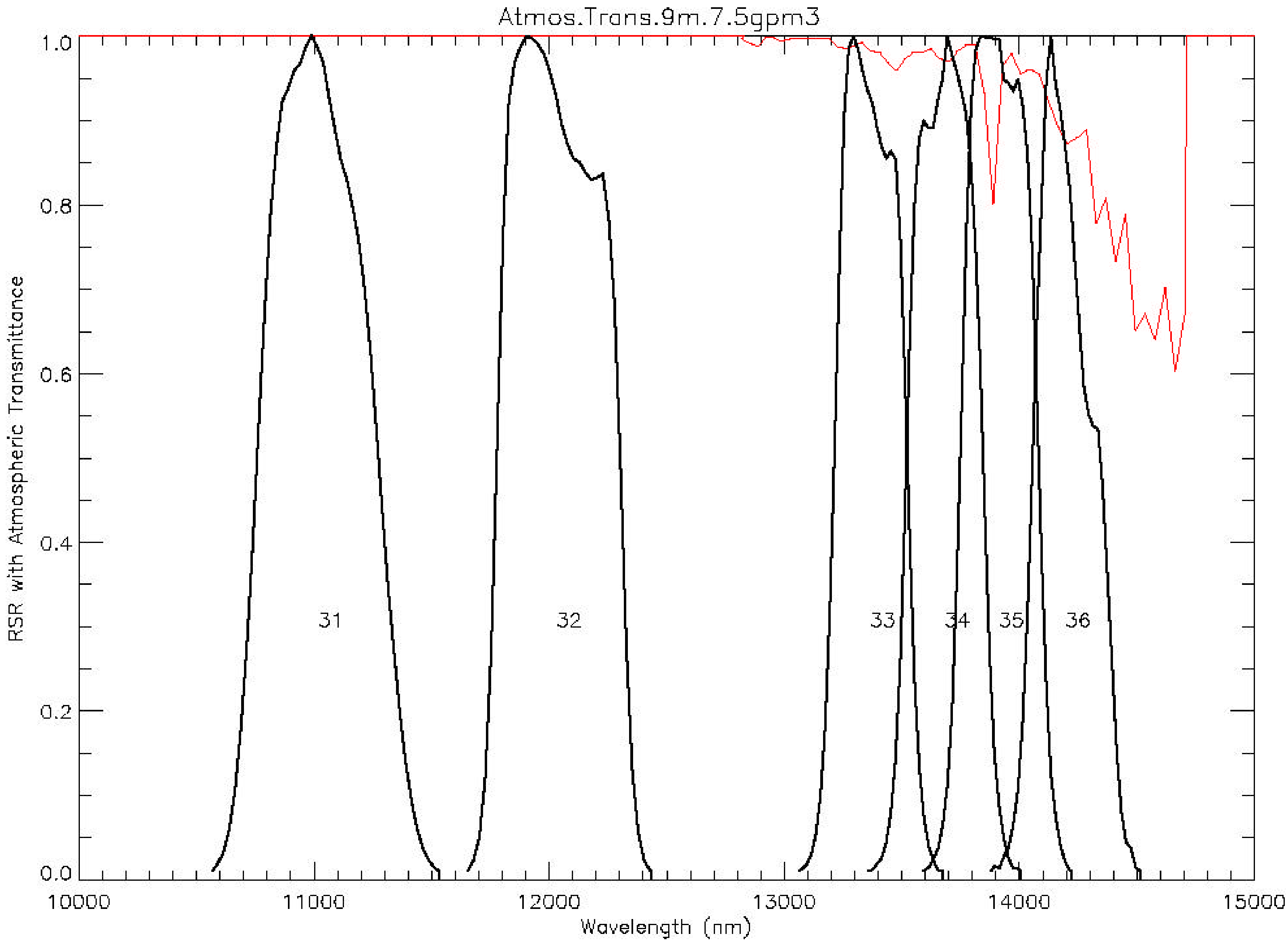
#	Band	Channel		CW		BW		EB1		EB2	Ripple	1%_on	1%_off	Centroid
	Spectral Response Analysis--Specifications Matching Report													
*	8	5		411.3		14.0	H	12.9		4.3	91.2%	399.5	428.1	411.7
	9	5		442.0		9.7		4.8		4.0	82.1%	432.9	460.0	441.9
	3	10		465.0		18.2		4.3		5.7	82.4%	451.3	490.5	465.5
	10	5		466.9		10.6		4.4		3.2	81.1%	477.2	495.0	488.8
*	11	5		520.6	H	12.0		4.2		5.0	80.3%	519.5	540.2	529.6
	12	5		548.8		10.3		4.6		4.4	86.5%	537.1	565.9	546.7
	4	10		553.8		19.8		4.0		4.3	90.8%	538.5	560.0	553.5
*	1	20		645.0		48.0	H	24.4		13.5	81.0%	614.0	681.2	646.1
*	13	5		685.5		10.1		4.9	H	5.8	90.0%	655.7	674.0	665.6
*	14	5	L	676.8		11.3	H	5.8		3.5	84.6%	665.1	687.7	676.7
*	15	5		746.4		8.9	H	5.7	H	5.4	85.6%	736.5	756.8	746.3
	2	20		858.5		38.4		18.1		12.1	90.6%	815.2	899.0	866.1
	16	5		868.2		15.5		7.6		8.8	82.3%	850.8	891.4	866.0
	17	5		904.0		35.0		13.2		12.4	91.1%	870.4	938.1	904.0
*	18	5		935.5		13.6	H	6.8		6.5	80.2%	922.0	948.4	935.4
*	18	5	L	935.2		46.1		21.7		19.4	82.0%	963.0	960.4	935.9
*	5	10		1241.6		24.0	H	13.8	H	13.4	83.0%	1214.0	1271.4	1241.7
*	26	5		1383.0		35.0	H	27.0	H	19.1	80.7%	1337.3	1421.1	1381.7
*	6	10	L	1629.1		28.6	H	14.6	H	15.1	84.4%	1596.4	1661.1	1628.0
*	7	10	L	2114.1		59.7		20.6	H	33.0	80.8%	2056.0	2175.1	2114.1
*	20	5	H	3785.0		187.7		45.6		64.2	82.0%	3621.1	3956.9	3786.7
*	21	5	H	3990.0	H	84.4		37.3		37.1	80.7%	3932.7	4079.3	3990.2
*	22	5		3970.1	H	87.6		38.5		31.6	84.1%	3876.5	4058.7	3970.1
*	23	5		4056.4	H	86.7		38.9		29.1	82.0%	3935.1	4137.3	4055.0
	24	5		4471.7		91.7		40.1		35.3	83.3%	4382.4	4556.7	4471.7
*	25	5	H	4545.2		92.0		43.4		34.8	87.4%	4452.1	4630.1	4544.0
*	27	5	H	6752.4	L	248.1	H	175.5	H	172.8	82.0%	6463.4	7145.1	6757.3
	28	5		7333.6		327.5		150.4		145.7	80.2%	6906.4	7600.2	7330.1
*	29	5		8626.2	H	361.1	H	215.3		168.2	80.5%	8090.3	8891.2	8512.5
*	30	5	L	8661.0	L	314.6	H	237.6	H	217.0	82.9%	9273.9	9946.2	8661.6
	31	5		11017.2		536.7		192.6		265.9	80.8%	10552.4	11526.5	11015.7
	32	5		12092.4		524.6		108.2		140.5	82.3%	11545.2	12422.2	12025.1
	33	5		13358.0		310.3		109.5		126.0	84.2%	13054.8	13671.5	13358.2
	34	5		13674.5		326.9		118.3		130.5	85.5%	13350.7	13984.7	13674.6
	35	5		13907.0		333.4		115.0		122.4	80.7%	13565.8	14212.1	13908.4
*	36	5		14191.5		289.8		130.8	H	227.2	81.3%	13882.3	14509.2	14189.7

5/2/97 1:31 PM

MODIS Waiver #075
Attachment 2
5/2/97


OOB-ND Blocking Filter Transmissions
Superimposed on MWIR and LWIR RSRs
20
27
28
29
31
32
33
(%) Transmission
100.000
10.000
1.000
0.100
0.010
0.001
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Wavelength (um)
Filter 15


Atmos.Trans.9m.7.5gpm3
RSR with Atmospheric Transmittance
Wavelength (nm)
1.0
0.8
0.6
0.4
0.2
0.0
6000
7000
8000
9000
10000
27
28
29
30



Atmos.Trans.9m.7.5gpm3
RSR with Atmospheric Transmittance
Wavelength (nm)
1.0
0.8
0.6
0.4
0.2
0.0
10000
11000
12000
13000
14000
15000
31
32
33
34
35
36

Figure 1. PFM B5 $\langle dn_{SB} \rangle$ of Sub-frame 1, 2, and their Difference

OBC Data Sets Selected during OA-26 (Day_293)
(Blackbody Cool-down Activity; Itwk:79/Vdet:110)

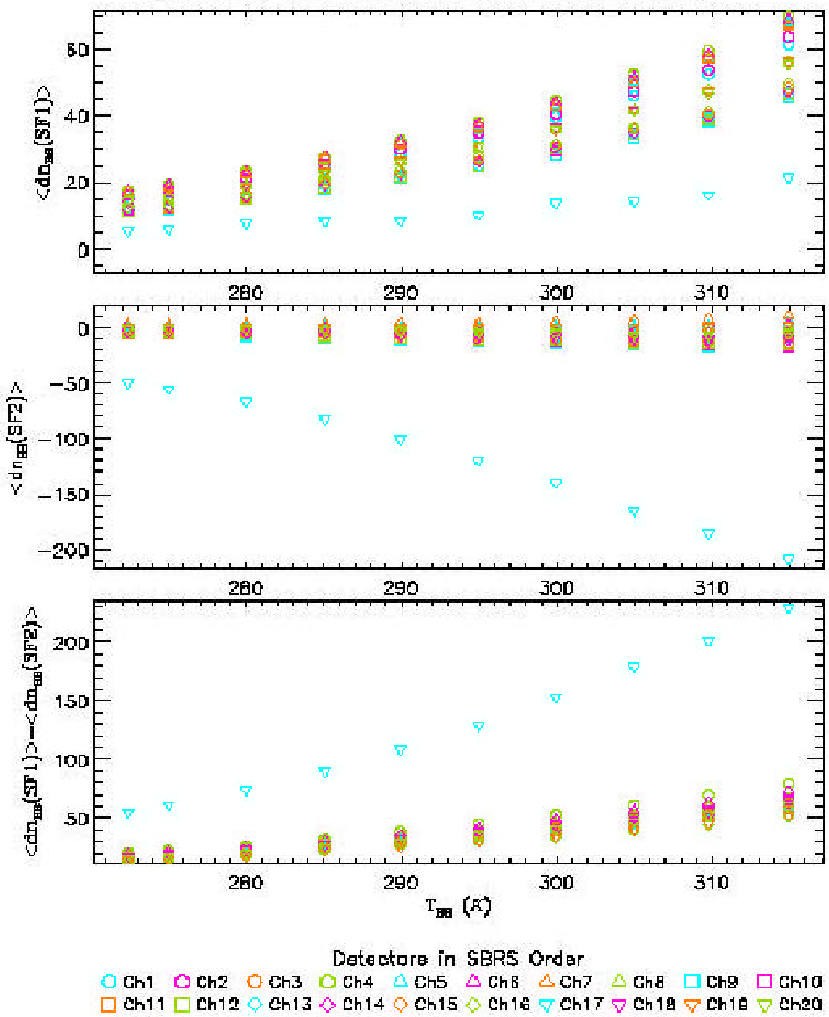
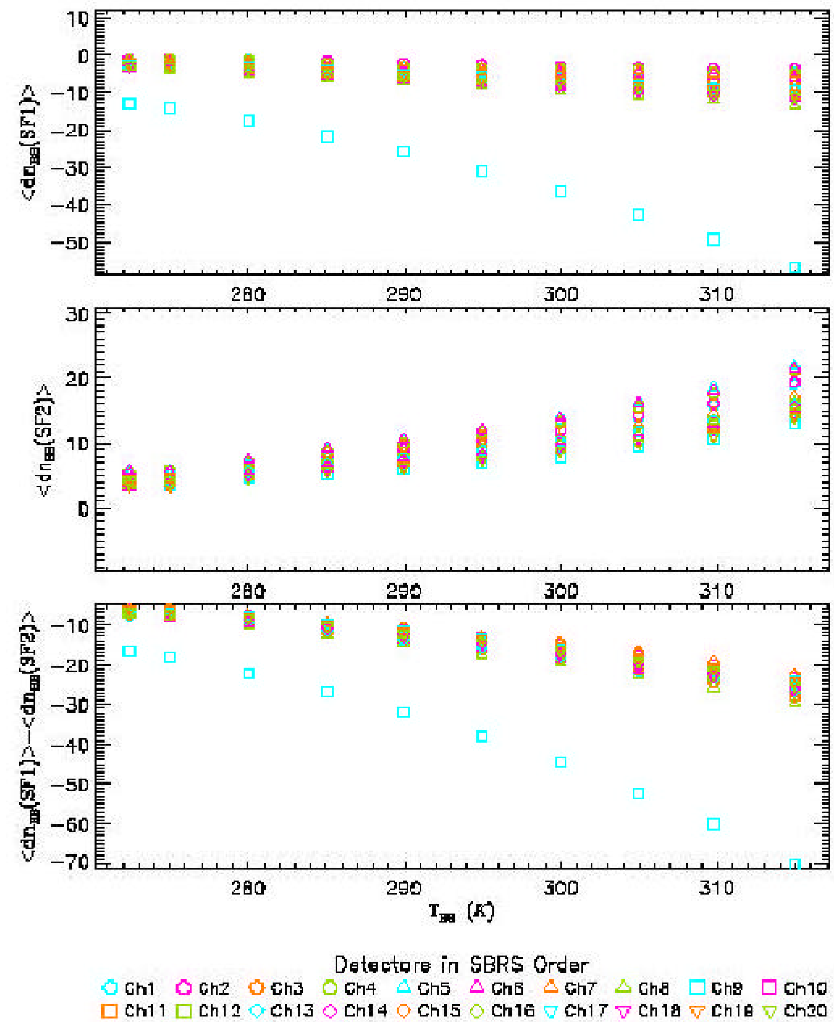
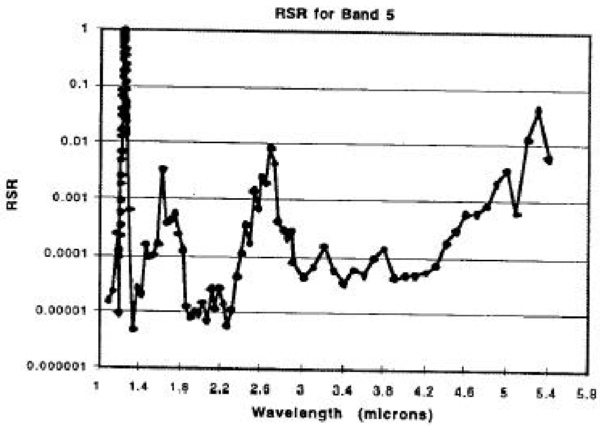


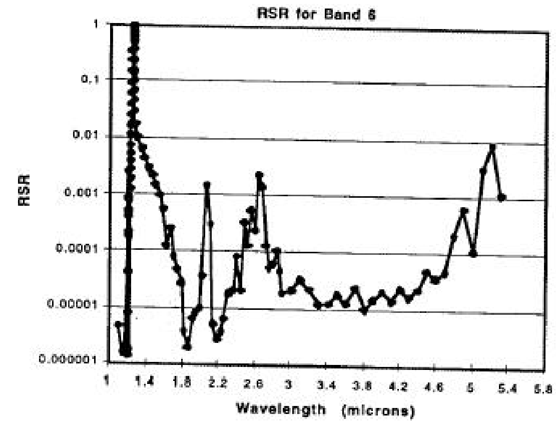
Figure 2. PFM B6 $\langle dn_{SB} \rangle$ of Sub-frame 1, 2, and their Difference

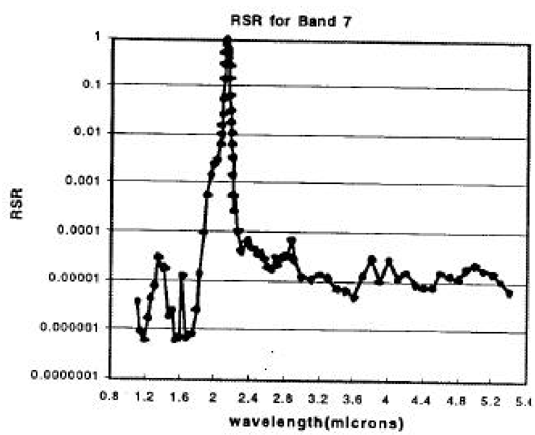
OBC Data Sets Selected during OA-26 (Day_293)
(Blackbody Cool-down Activity; Itwk:79/Vdet:110)

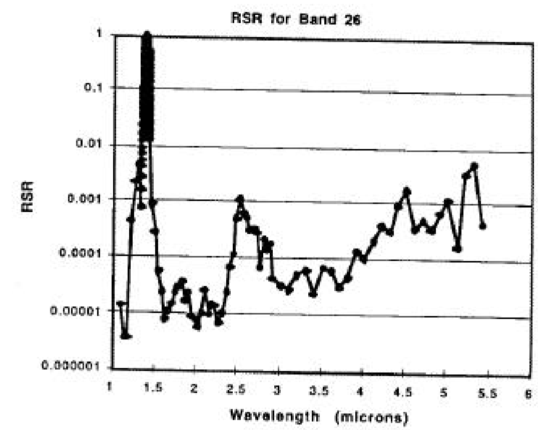


Relative Spectral Response (RSR)

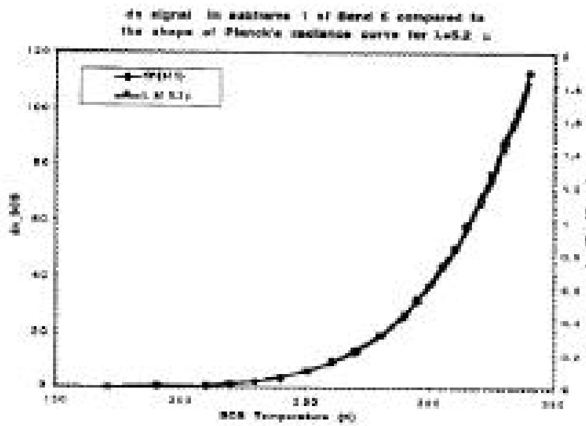


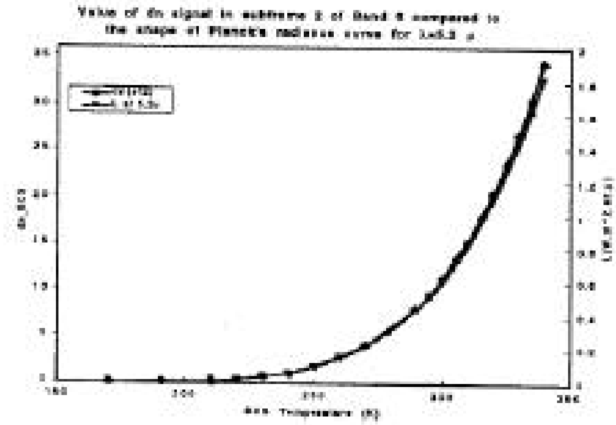


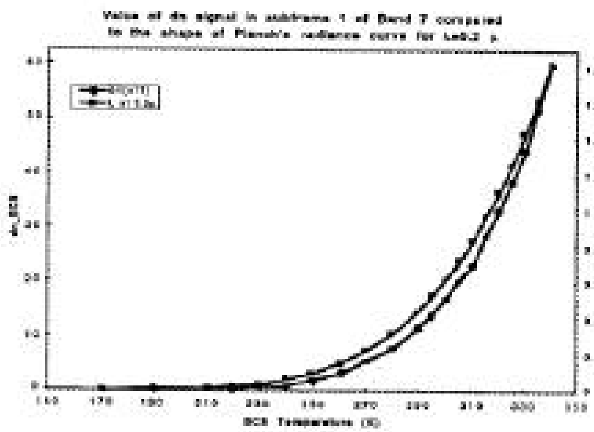


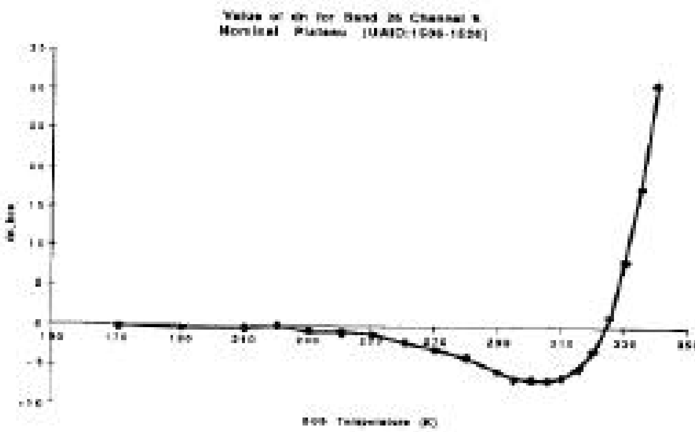


Behavior of SWIR Signal with BCS Temperature





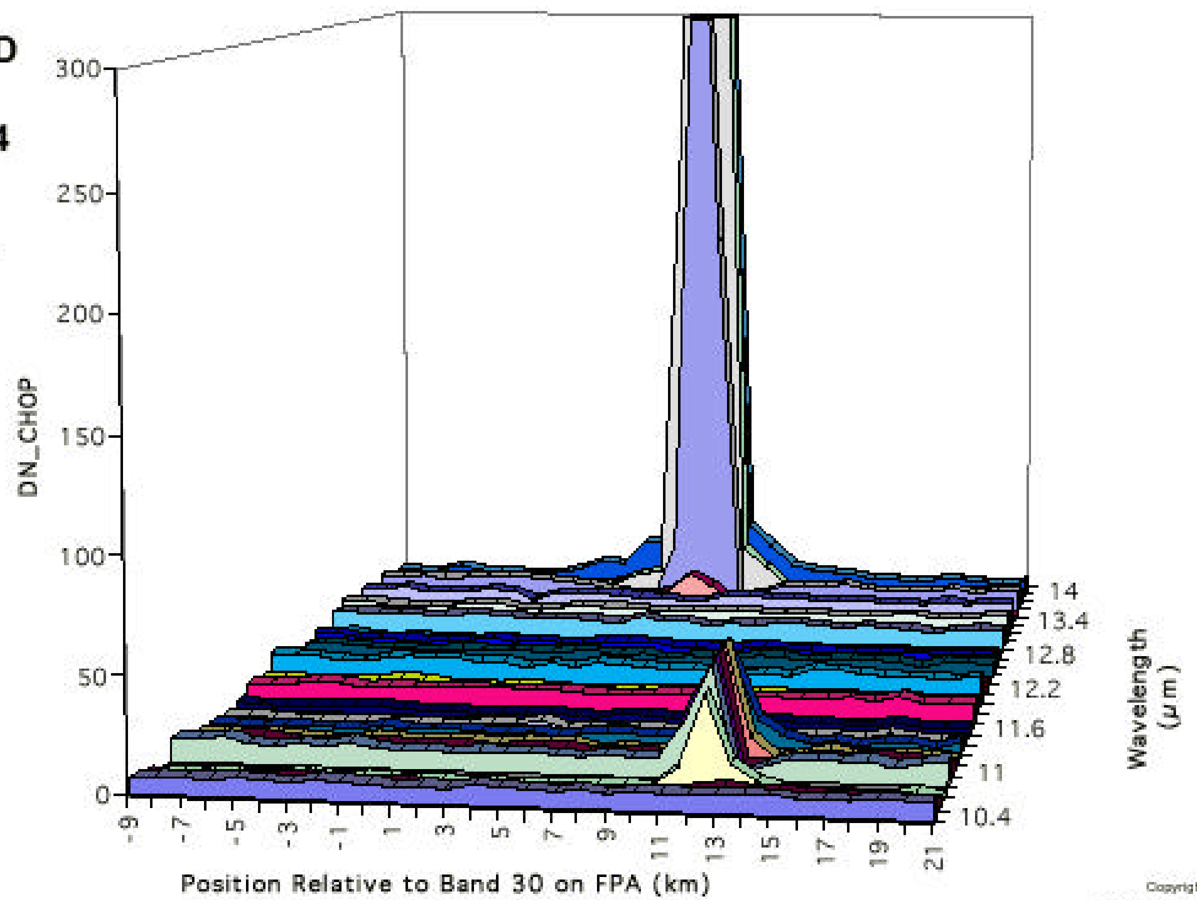


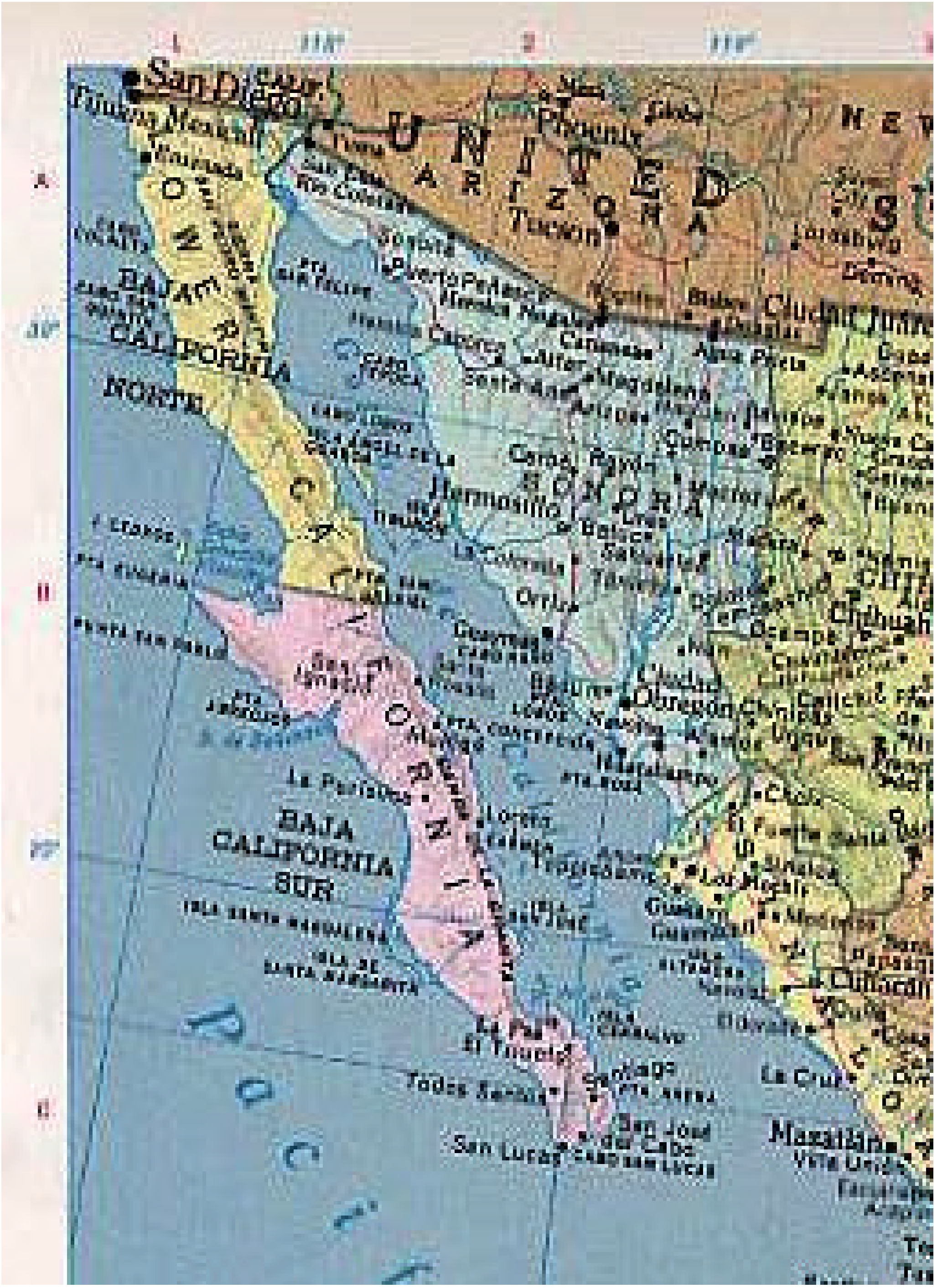


Pre-launch Crosstalk Observation
(Spatial/Spectral OOB Response Testing)

BAND 35 SPECTRAL AND SPATIAL RESPONSE

- DATA ACQUIRED DURING OOBD SCAN FROM 10.4 TO 14 µm
- RESPONSE NOT VISIBLE IN BANDS 31-33

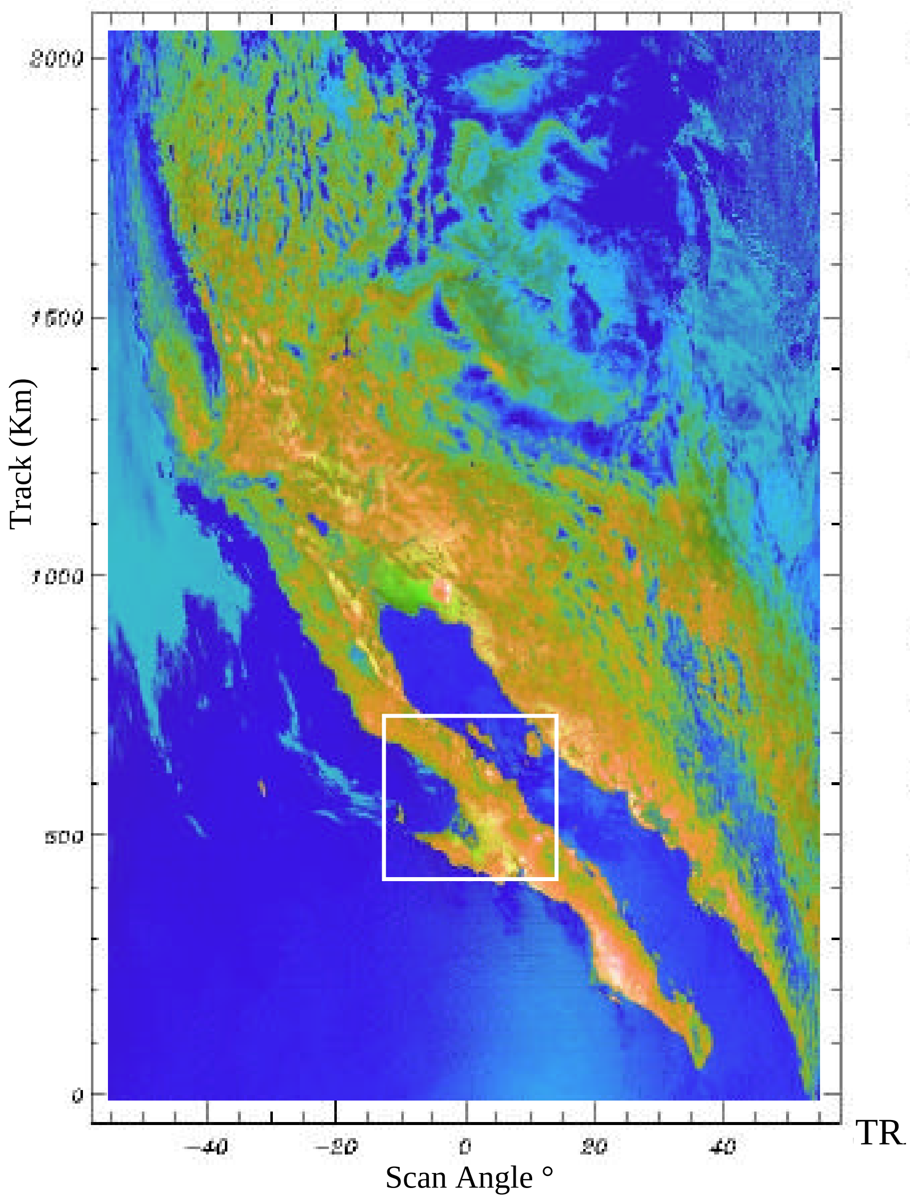


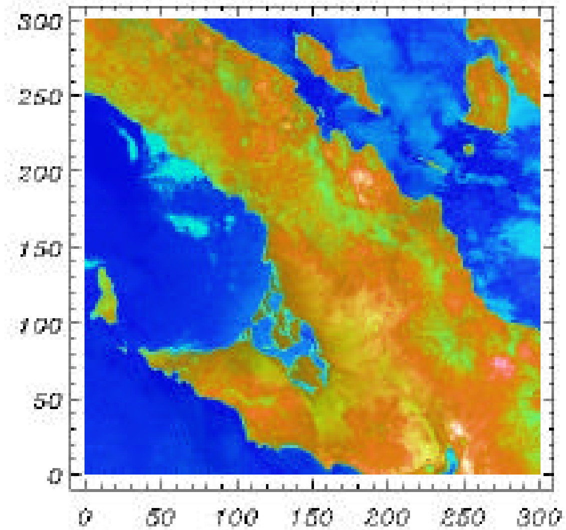


Baja, California

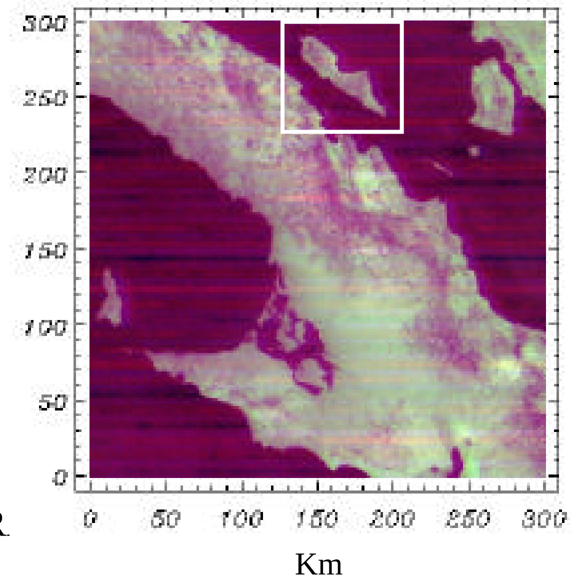
Selected Image Area
(28N 114W)
Isla Angel de la Guarda

Baja California (094.1835; Day Mode) Enhanced Radiance Images (*before* PC_XT Correction) in True Color





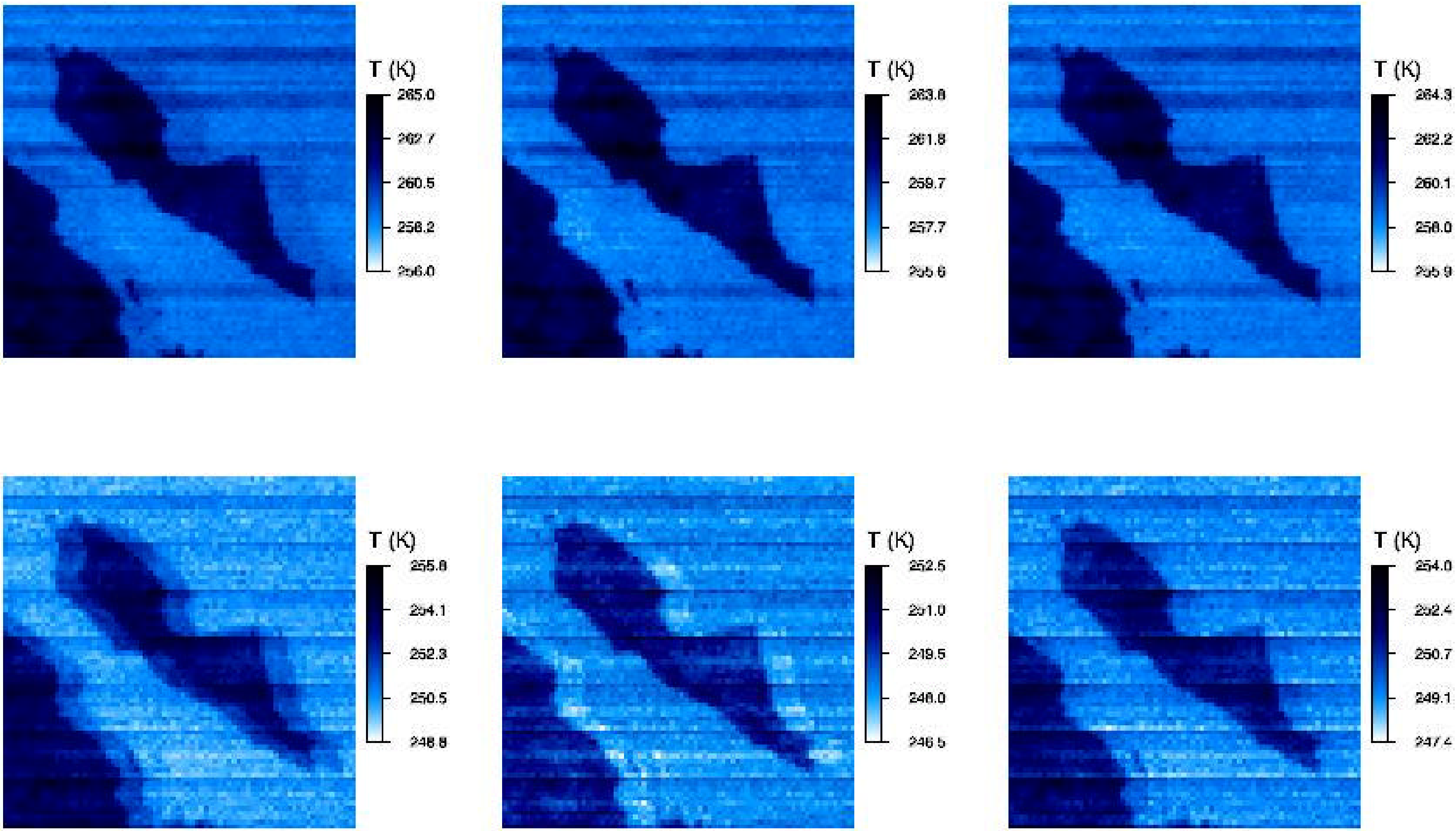
B29 (**R**)
B20 (**G**)
B31 (**B**)

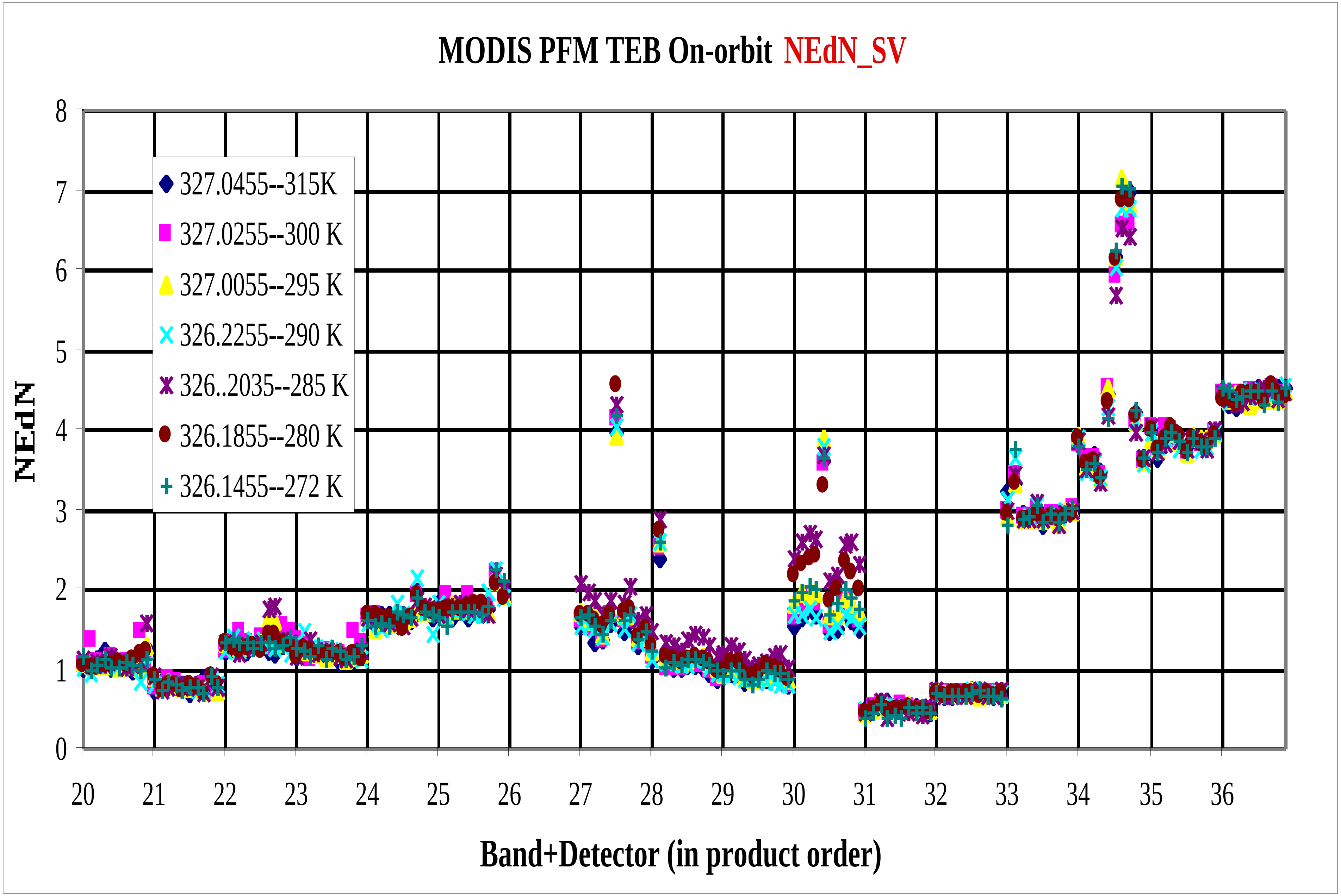


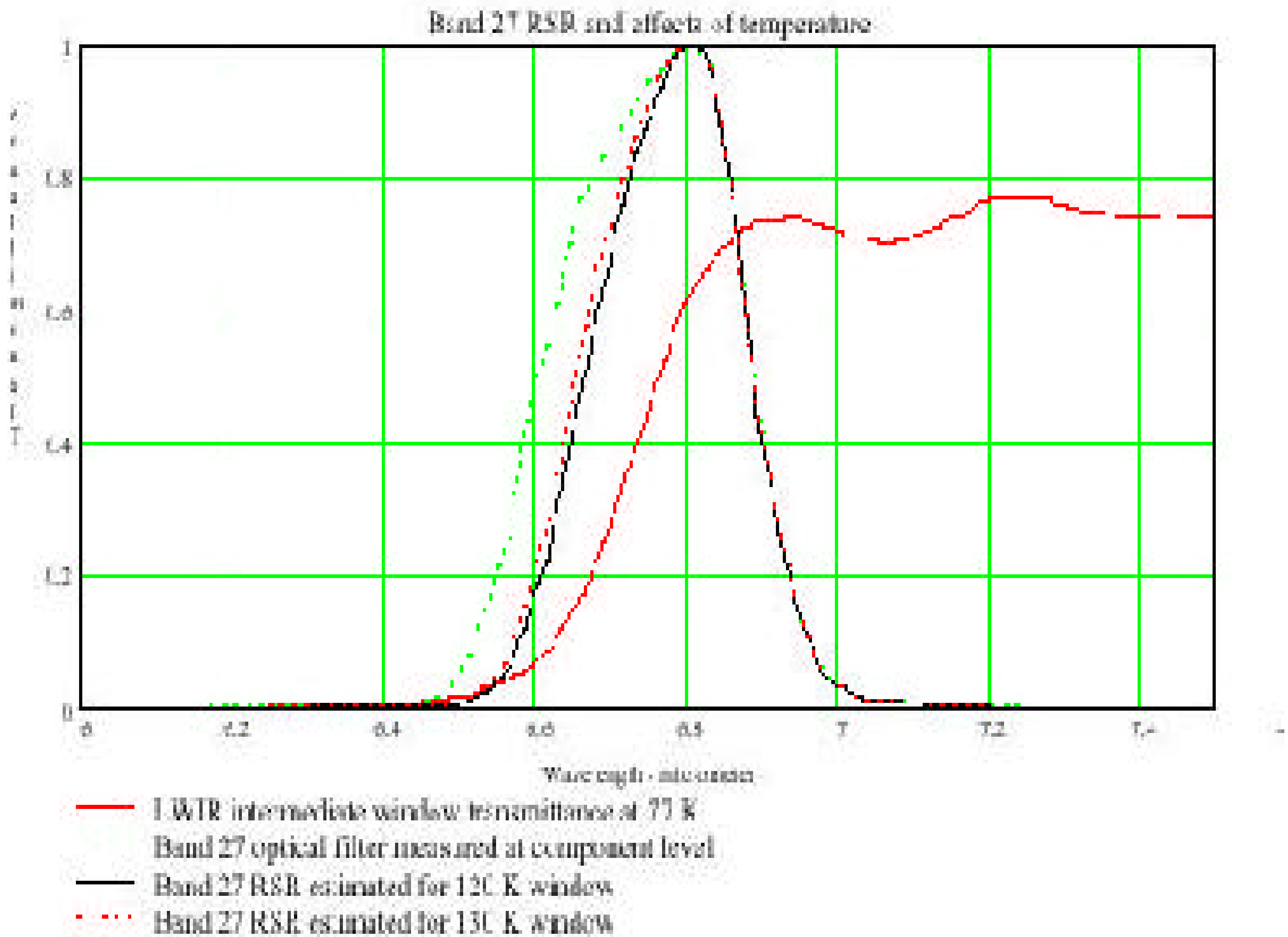
B***34*** (**R**)
B31 (**G**)
B***35*** (**B**)
Cross-Talk Observed

Band 34 (Top) & Band 35 (Bottom) (94/18:35)

No Correction | Pre-launch Correction | New Correction




MODIS PFM TEB On-orbit NEdN_SV
NEdN
Band+Detector (in product order)
327.0455--315K
327.0255--300 K
327.0055--295 K
326.2255--290 K
326..2035--285 K
326.1855--280 K
326.1455--272 K
0
1
2
3
4
5
6
7
8
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36



Band 27 RSR and affects of temperature
Wavelength - micrometer
LWIR intermediate window transmittance at 77 K
Band 27 optical filter measured at component level
Band 27 RSR estimated for 120 K window
Band 27 RSR estimated for 130 K window

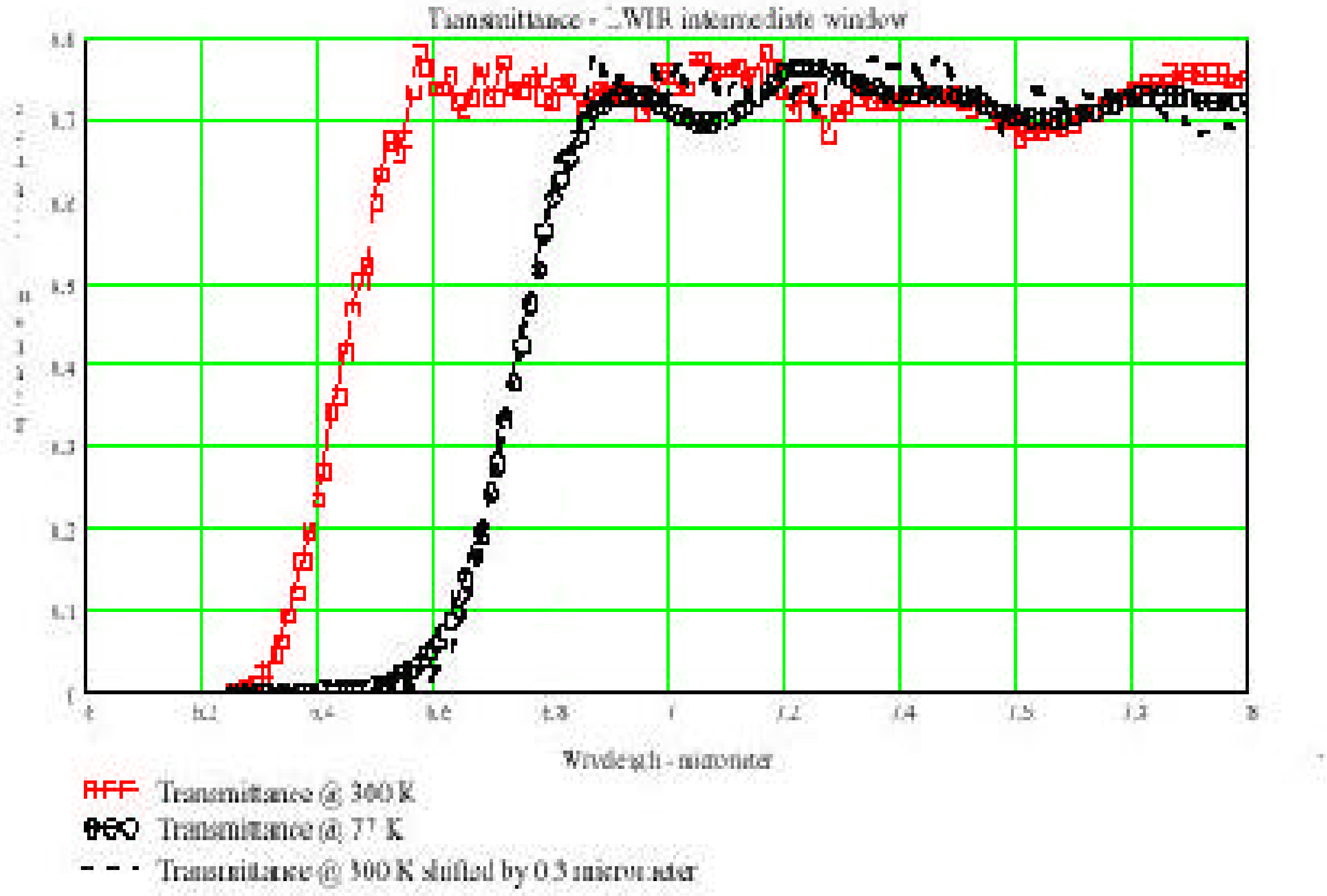
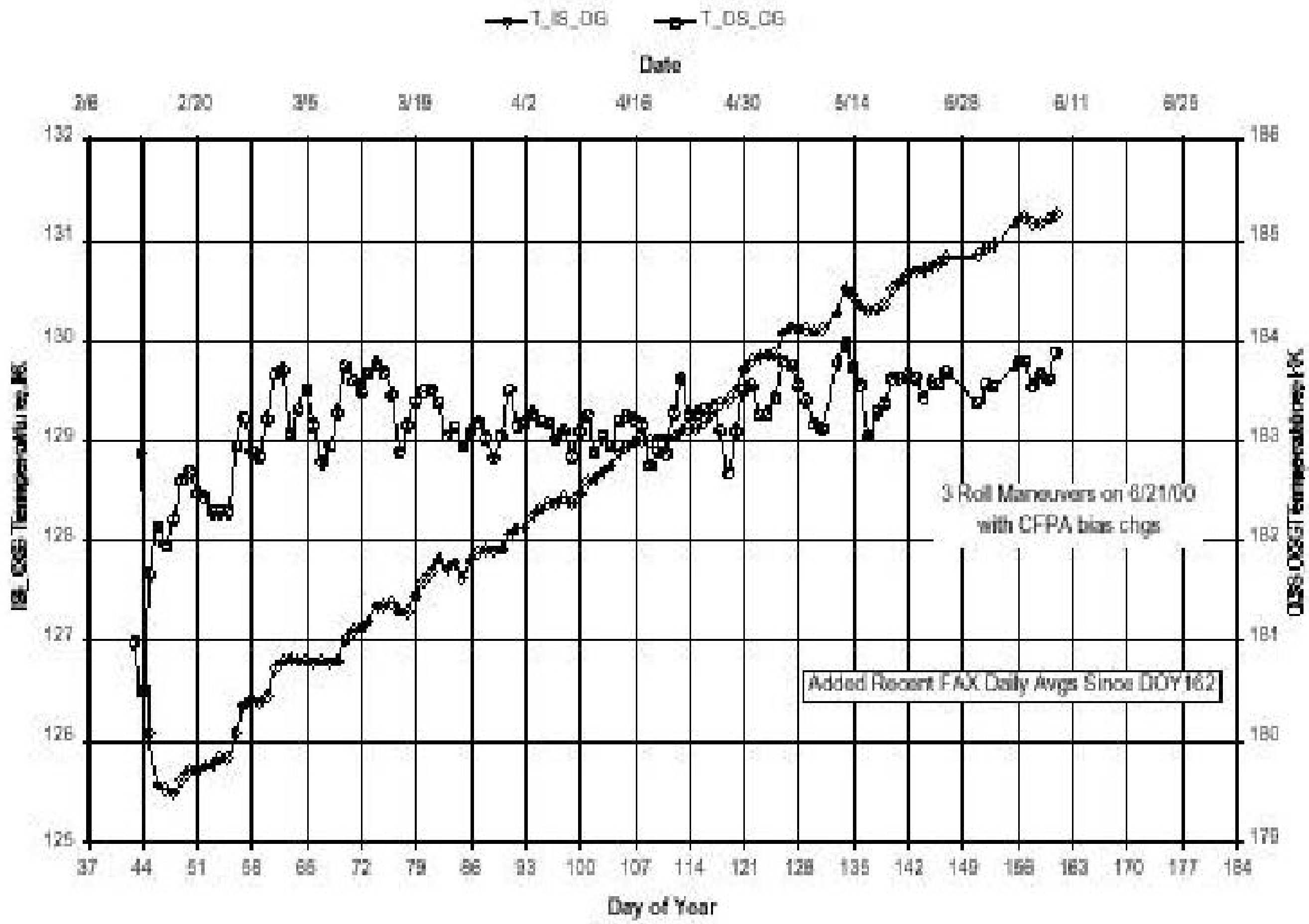


Figure 5. LWIR intermediate window spectral transmittance for 300 K and 77 K.

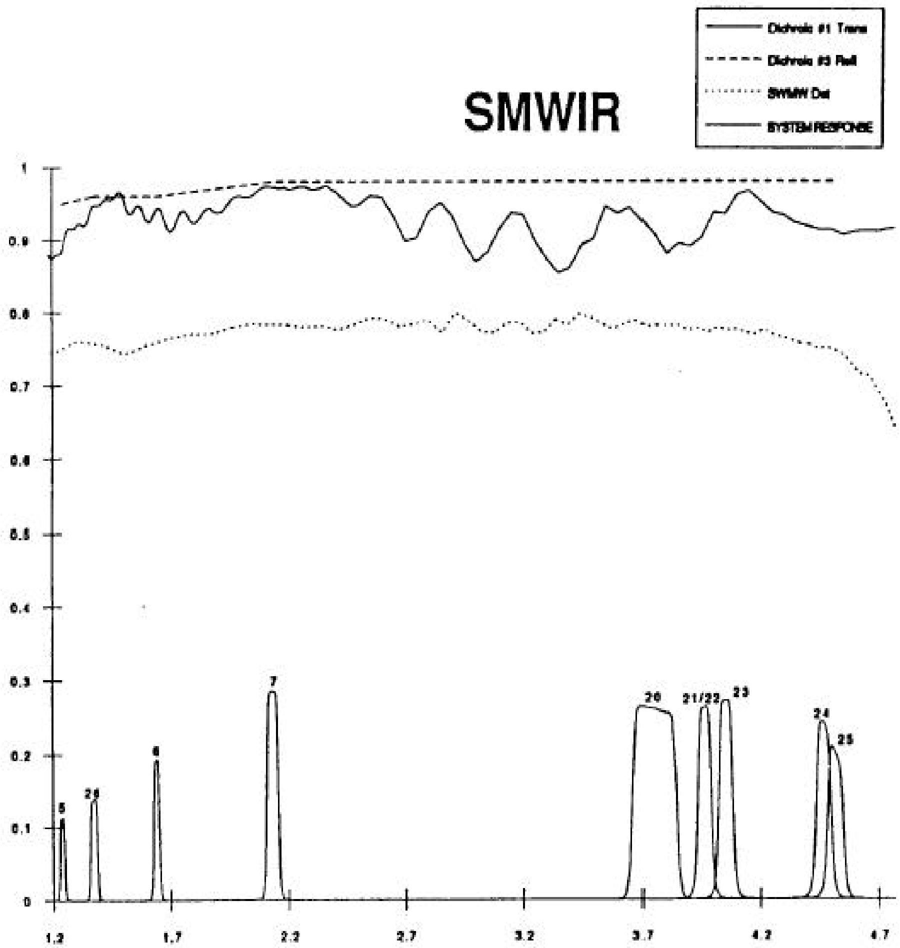


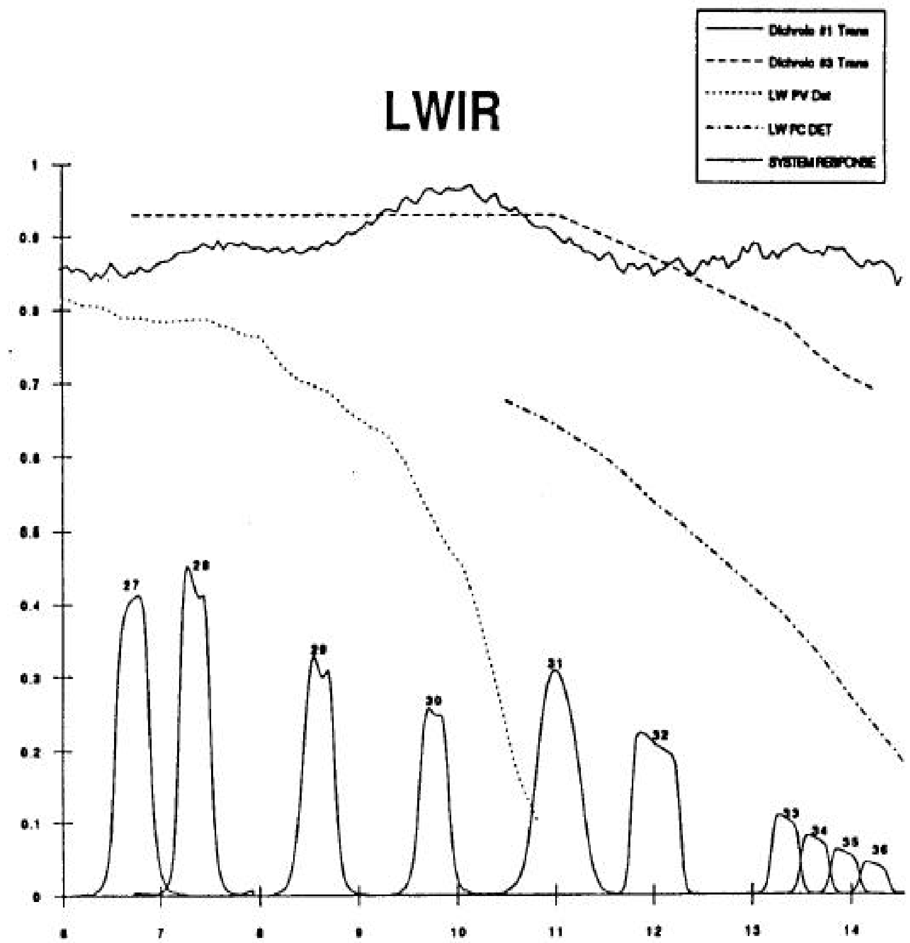
T_IS_OG
T_OS_OG
Date
Day of Year
3 Roll Maneuvers on 6/21/00
with CFPA bias chgs
Added Recent FAX Daily Avgs Since DOY 162

MODEL IDENTIFIES KEY CONTRIBUTORS TO SYSTEM WAVELENGTH, TRANSMISSION (SMWIR, LWIR)

HUGHES

SANTA BARBARA RESEARCH CENTER
a subsidiary





11/93
93-0868-110B

Figure 4 illustrates the effect of polarization on the shape of band 8 relative spectral response.

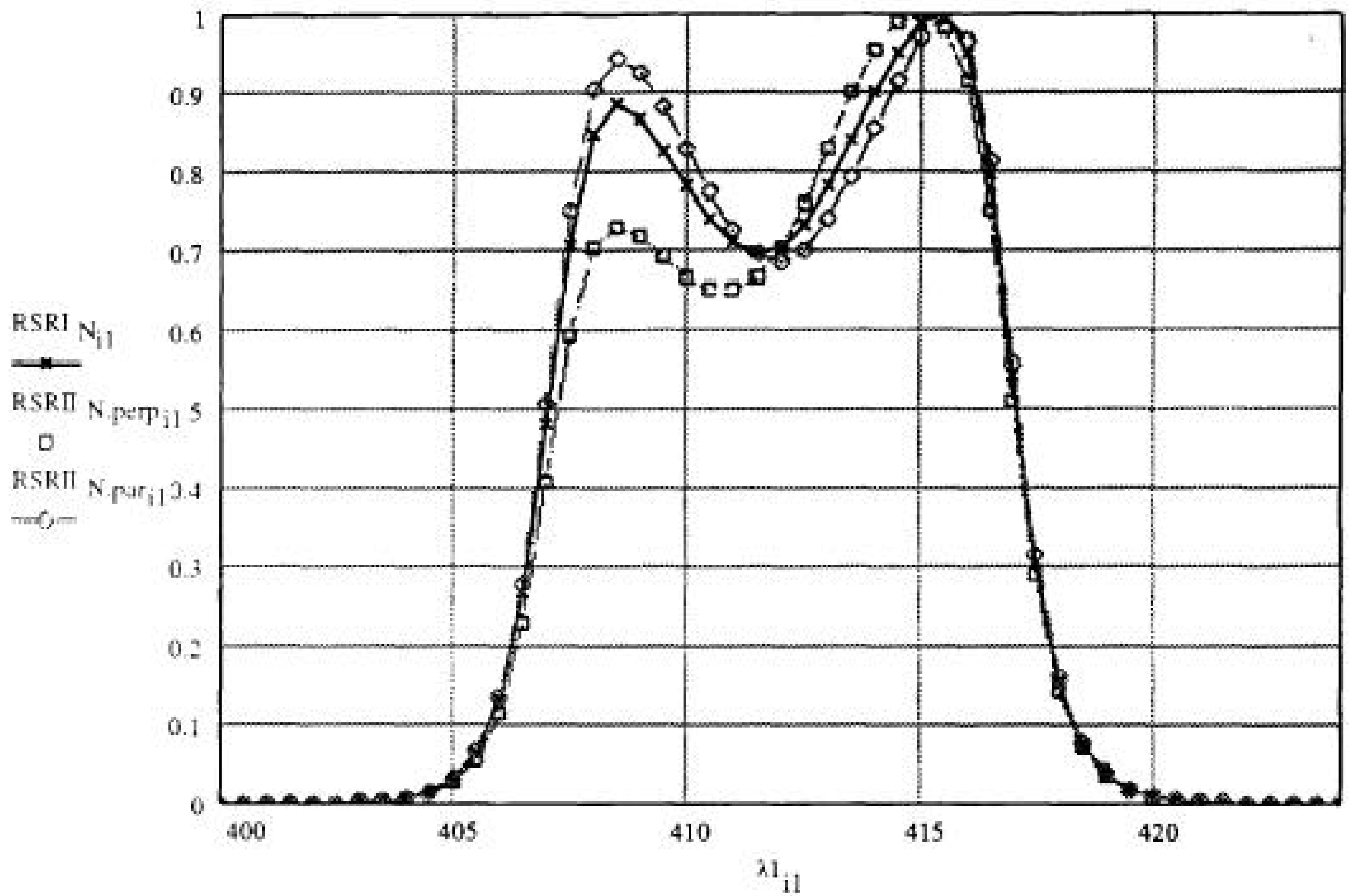
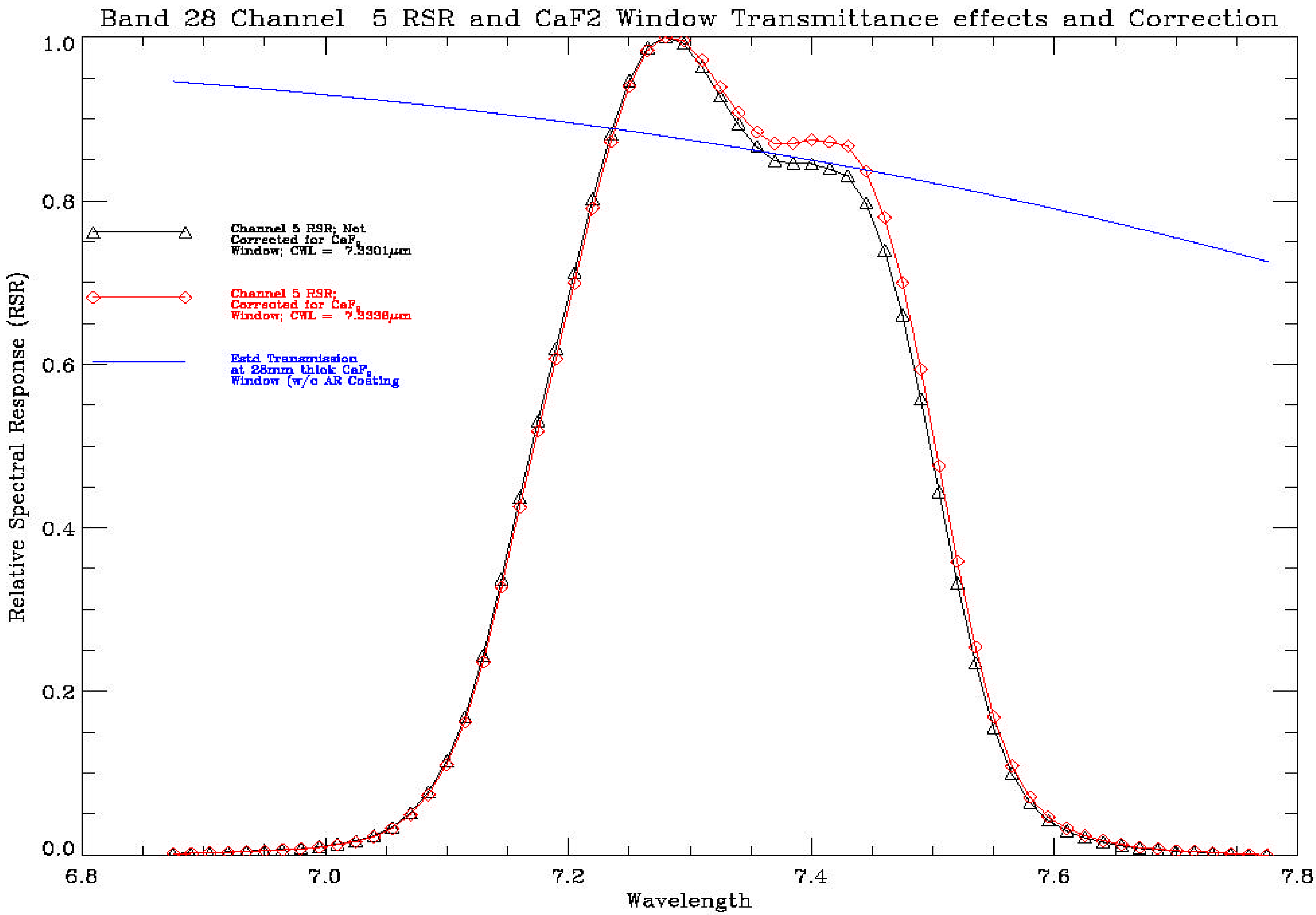


Figure 4. The simulated relative spectral response functions for case I (unpolarized) and case II (polarized).


Band 28 Channel 5 RSR and CaF2 Window Transmittance effects and Correction
Channel 5 RSR; Not Corrected for CaF_2 Window; CWL = 7.3301μm
Channel 5 RSR; Corrected for CaF_2 Window; CWL = 7.3336μm
Estd Transmission at 28mm thick CaF_2 Window (w/o AR Coating
Relative Spectral Response (RSR)
Wavelength
1.0
0.8
0.6
0.4
0.2
0.0
6.8
7.0
7.2
7.4
7.6
7.8